ORAL HISTORY ARCHIVES

77: TIFR Archives, Mumbai

Introductory Materials

Administrative and Legal Information

The Oral History Archives of the Tata Institute of Fundamental Research (TIFR) began as a project in September 2002 with financial support from the TIFR Endowment Fund and the National Centre for Biological Sciences (NCBS), Bangalore. Indira Chowdhury, who planned and initiated this project, was granted research leave with full support from her institution, Jadavpur University, Kolkata. Housed at the NCBS, the project started interviewing scientists who started the Molecular Biology Group at TIFR in 1962 that later extended to form the National Centre for Biological Sciences at Bangalore. From 2004 onwards, the project extended to include other TIFR scientists, administrators, scientific and workshop staff and associates of the founder, Homi Bhabha.

The aim of oral history is to create and preserve resources that would contribute to existing historical records. Oral histories are spoken responses to an interviewer's questions. Oral histories are factual accounts, although their personal and participatory render them inevitably into insightful re-examinations of past events. Oral histories can be biased at times; but they make no claim to being the final and definitive version of any historical event. They are undoubtedly unique and priceless resources. Moreover, since historical documents about science institutions in India are not always readily available, this oral history project marks a significant beginning by making available a new archival resource that can be accessed by historians of science as well as interested members of the general public.

The present collection of oral history interviews attempts to capture the context in which the Institute developed. The tape-recorded interviews are

transcribed, lightly edited for continuity and clarity, and reviewed by the interviewee. The process of interviewing has also given the project the opportunity to access correspondence and photographs from the private collections of scientists. The photographs and correspondence has been included with the oral history transcriptions. A copy of the corrected manuscript is indexed, bound with photographs and illustrative materials and placed in the TIFR Archives, Mumbai for scholarly use.

Requests for permission to quote for publication should be addressed to The Archivist, TIFR Archives, Tata Institute of Fundamental Research, Homi Bhabha Road, Colaba, Mumbai 400005, Maharashtra, India and should include identification of the specific passages to be quoted, anticipated use of the passages, and identification of the user.

All uses of this manuscript are covered by an agreement between The TIFR Archives and Professor Govind Swarup dated___. The manuscript is thereby made available for research purposes. Copyright has been assigned to the Tata Institute of Fundamental Research Archives, Mumbai © 2009.

Preferred citation

Swarup, Govind. Oral history interviews conducted by Indira Chowdhury. Pune, India, 17 January 2005 – 10 February 2005, TIFR Archives.

Contact information

TIFR Archives,
Tata Institute of Fundamental Research
Homi Bhabha Road,

Colaba, Navy Nagar

Mumbai 400005

Phone: 022-22782560

Email: archives@tifr.res.in

Graphics and content © TIFR Archives.

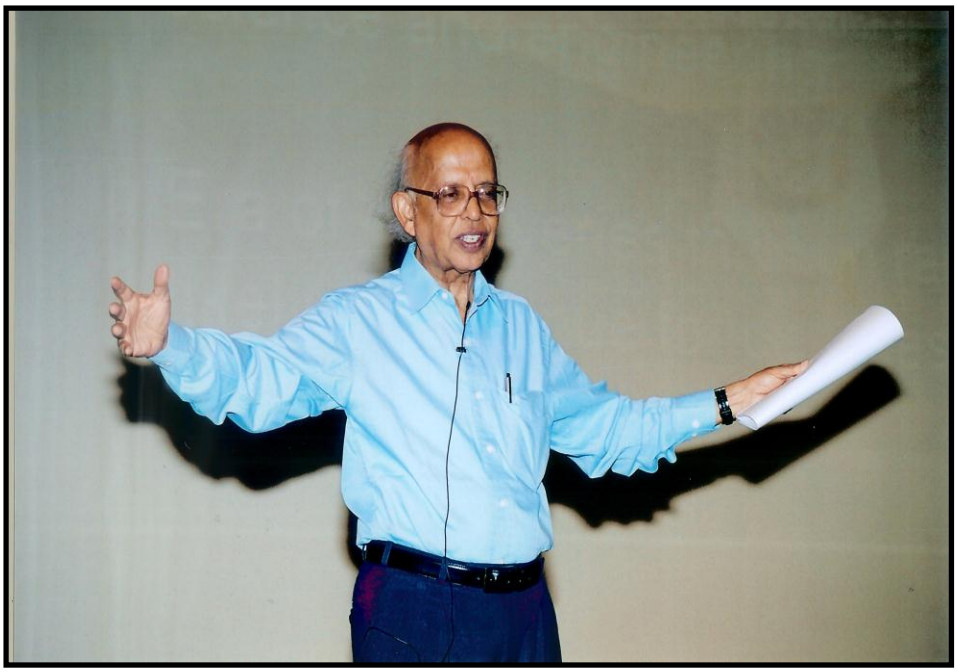
Oral History of Radio Astronomy at TIFR

TIFR Archives, Mumbai

Govind Swarup (-)

Interviews conducted by Indira Chowdhury

17 January 2005 – 29 April 2006



Session One
Date: 17th Jan, 2005
Venue : NCRA, Pune

Indira Chowdhury: Prof. Swarup we could start with your childhood and family.

Govind Swarup: I was born in a house of rich parents. You may say I was born with a silver spoon. The house I was born in was built in 1919 at a cost of about Rs. two lakh.

IC: Where was it?

GS: It was in a small town called Thakurdwara in the District Moradabad of U.P.

IC: Towards Nainital**?**

GS: Yes, about 50 km north east from the city of Moradabad towards the Nainital District and 10 km north from the town of Kashipur.

IC: What did your family do?

GS: My family members were *zamindars* for over hundred years. In 1905 my great grandfather and his cousins installed a spinning mill in Moradabad. This brought them lots of money during the World War I.

IC: Were these spinning mills brought from Manchester?

GS: Manchester or Liverpool, I am not sure. My father is not there now to confirm. After that the money earned from the Spinning Mill was used for a variety of businesses, none of which worked very well. You can find that out from my father's diary. My father was interested in theatres and built firstly a temporary cinema hall in Delhi in which he showed the first talking Hindi Movie including the well known AlamAra. Using the money earned, he built the first brick theatre quiet close to Chandni Chowk in Delhi in 1935.

IC: What was it called?

GS: It was called Jubilee as far as I remember - or Krishna Talkies. That was shut down and sold because of my uncle. It's a long story. I will tell you some other time. And that brought the partition between two brothers. My father inherited properties in and around Thakurdwara and the prosperous village Dhoti west of Moradabad. So my father had to shift in 1937 to the small town of Thakurdwara, after having lived in Delhi for about 7 years. My father was very enterprising. During his stay at Delhi, he also established a garage in Connaught Place, which sold cars. Once he sold cars to the *Maharaja* of Patiala, who never gave the money. During 1930s, my father also established a 200 acre farm in the village named Dhauti, about 30 km away from Moradabad, which he inherited as part of Zamindari after partition with my uncle. I remember so well many summer and winters walking in the farm during my school and college holidays. There was a large 'oxbow' lake adjacent to our farm, created by meandering of the Ganges River, which got filled by the overflowing Ganges River in Monsoon adjacent to the boundary of the farm. I remember watching crocodiles on its bank for hours. During 1950s, the farm was sold to many farmers due to various circumstances.

IC: How many siblings did you have?

GS: We were four brothers and four sisters. The eldest sister died when she was 12 and then the second one died soon after her marriage due to a serious illness. Only I and my immediate elder brother are now alive.

IC: Where you were you born in Thakurdwara?

GS: I was born in 1929 in a room used for giving birth in our house at Thakurdwara. The mother and baby were kept isolated in the house for 30 days to avoid infections. There was no hospital in the town only a clinic.

IC: You studied there?

GS: Yes I studied there from the third standard to the seventh. Up to third standard, my brothers and cousins used to go a *pathshala* or studied under home tutors. But my grandfather did not support that for me and rather taught me informally. He had done his B.A in 1895 with distinction. I have a copy of his degree certificate.

IC: From where?

GS: Allahabad University. He had studied English, Philosophy and Persian. And he was among the very few graduates at that time from UP, particularly in the Agarwal family. He was very particular that there would be no tutor for me. The earliest recollection I have is sitting on a bed in his room and solving problems given by him. In those days you didn't only fear your father but your grandfather also. He used to give me mathematical problems to solve. I studied under his guidance. Then in the third standard I got into a small school in Thakurdwara. The school was in our ancestral property that was donated to that school. The only thing I remember is that once my Hindi teacher made me stand on the bench. That was a great lesson for me.

IC: From where did you pass your matriculation?

GS: In 1941, my father shifted to Moradabad from Thakurdwara, and I joined the seventh standard in the Coronation Hindu High School in Moradabad. There mathematics and science teachers influenced me a lot.

IC: We will come to that. Was your family politically inclined or nationalistic?

GS: They were partly inclined to the Englishmen because they were *zamindars.* But I don't think they gave any donations to them. But some of my uncles were towards the freedom movement. Particularly I remember a schoolboy in the town of Thakurdwara, who was supposed to be making bombs and disappeared. So there is quite a history about Thakurdwara, including that of the highly notorious Sultana *daku.* In 1944 I got the Autobiography of Gandhiji from the school at Moradabad as a reward for being the best character in the school. I was a studious child. All the boys used to say, '*Bahut bewakuf hai tabhi to aisa award mila*.' I passed high school with first division and distinction. My mother is from a very famous family of sugar mills of Mujaffarnagar. For example one of my mother's cousin's daughters got married to S K Modi of the Modi Enterprises. So that's the kind of family. My *nana (maternal grandfather)* was very supportive to give higher education to his children. So he sent 3 out of 8 sons to England. His first son looked after family business. His second son became a civil surgeon, the third one was in railway engineering service who rose to become Chief Engineer and was responsible to set up India's first

Integral Coach Factory in Madras (later became the Southern Structural Ltd that built 15 out of 30 antenna of the GMRT in 1990s 40 years later), and fourth became an IPS officer retiring as Dy. Dirctor General. Another became the registrar at IIT Kanpur. Two of my *mamas* had studied in Allahabad. My mother was very keen that I go to the Roorkee Engineering College or study railway engineering at Jamalpur as one of my Mama was in Railways, which would assure me a job. I was a weak child as Thakurdwara was a malarial region in *Terai* and I used to get malaria almost every year, plus z*amindari* was abolished and my father had lost too much of money so she was keen I get into a profession, not realizing that I did not have that kind of inclination. But one of my *mamas* insisted that I join the Ewing Christian College at Allahabad where he had studied. A cousin of mine had also studied in that College. My brother, 20 months older to me, who was very close to me, who had joined the Lucknow Christian College a year ago. He was doing Botany, Physics, Chemistry — I don't remember exactly — to get into medical services but was not happy there. So he decided to lose one year and both of us joined the Ewing Christian College. My elder brother gave me great support in the College in various ways. My years of 1944-46 in that college were extraordinary experience. The Ewing Christian College was one of the best known colleges, like the Foreman Christian College at Lahore, the Madras Christian College, the Ferguson College in Pune, St, Xaviers College, Bombay, etc. These were famous six or seven colleges that the British had built in different parts of India. The Ewing Christian College was supported by the American Presbyterian Church. There is an interesting story from when I went to Harvard. A Presbyterian rich farmer owning a large cattle ranch was dumbfounded when I told him that I went to that College. He told his wife, 'You know I have been sending US $ 100 to that

College every year and you say I am wasting the money. See this boy - he is in Harvard now!'

IC: I wanted to ask you that these were also the years when World War II was on and all kinds of things were happening in India. What was your experience?

GS: I became strongly nationalistic starting from Thakurdwara. Since Thakurdwara was close to the dense Forests, with Jim Corbett Park only ~20 kms away, there were some boys who were in the nationalist movement of Subhas Chandra Bose. And that was their hiding place.

IC: And you were aware of it?

GS: Yes I was aware of it. My family was very well educated so we were aware of the things going on there. I remember in 1942 when I was in the eighth standard, the Quit India movement started and my mother didn't want me to go to school that day. My elder brother was going and I was also very keen to go. We didn't know what would happen but we were going to shout Quit India in the school. Then some people came and told every one to get out from the school and to join a procession. In the process my brother lost me. And I remember there was a firing and I got scared. I jumped from a wire fence, which hurt me, and I was crying because I thought my mother would be very angry when I go home. I still remember this incident, because I was surprised that someone could fire at school children! Perhaps this incident, and also Premchand's novels made me nationalistic. India was agriculture economy at that era, with little manufacturing. Premchand wrote

in his novels that the middleclass was getting educated and getting rich with farmer's toil and they should contribute to India.

IC: So you were just thirteen?

GS: Yes. But I was old enough to read. Also I had good teachers. I told you about the Hindi teacher in Thakurdwara who got me interested in reading novels. There was a novel called S*hangrila*, a *Saraswati* series book, if I remember right. If you can get me that book in Hindi, I would be most delighted.

IC: Who is it by?

GS: It was translation of the book Lost Horizon by James Hilton, that I found years later when I saw a movie in Sydney in 1954. It was the story of an Englishman who was smuggled by Llamas to Tibet to modernize it. According to the story, Llamas had learnt to prolong their lives to hundreds of years and were living in harmony. As I recall, the Head Llama of Shrangila wanted a modern person to take over. You would enjoy reading that novel. My family was very religious, especially my mother. My father used to organize Ram Lila every year at Thakurdwara for 9 days with plays. On 9th day he recited the full Ramayana loudly for a few hours. But he was not so much into the traditional things in religion.

IC: What else would you read at that time?

GS: There were not many books in the Thakurdwara School at that time. My

mother had started subscribing to the well known monthly religious Kalyan magazine that published ancient tales and Hindu scriptures and I used to read every one of them. And there were special yearly issues; there was a thick book where all kind of tales from ancient scriptures were there. I don't remember the name. So I read all those.

IC: Mainly in Hindi or English?

GS: Hindi. I did not study English till I was in high school. There was not enough exposure to English, in UP. In the ninth-tenth standard, I started reading English. In the 9th standard, I was gifted one of Kipling's books, Kim, being the best student in the English Class, which all of us decided to burn because it was by an Englishman. This was the World War II years and the freedom movement.

IC: But you had read it?

GS: No I didn't read it. As the book was presented someone said, '*Tum isko padoge*?' I seem to recall, we got together and burnt it. *'Angreji kitab nahi padhni ha.'*

IC: But while all this was going on, did you have the experience of listening to either Gandhi or Nehru?

GS: Not till later. Not till I was in Allahabad. In the ninth-tenth I started reading English. I don't remember what type of novels I read. In Hindi I read Bankim Chandra and Sarat Chandra.

IC: So you had already read these novels in Hindi?

GS: Yes. These books were there in the school in Moradabad. There were no problems in borrowing books. Besides, my uncles also had libraries. And there were enough books all around. So I used to be an avid reader of novels.

GS: Coming back to your formative years, you just spoke about specific intellectual influences in school. What were those specific influences in Moradabad?

IC: The mathematics teacher named, Mr. Ghosh, influenced me and he made me to love subjects like algebra and geometry. I also remember the English teacher and the science teacher. Apart from that, there were influences of Subhas Chandra Bose in Thakurdwara. Many people used to talk that freedom movements started from small town. After I passed the tenth standard, I become a serious student and didn't get involved in any of those things.

IC: Which year did you pass your tenth?

GS: in 1944. I then joined the Ewing Christian College at Allahabad, where Mr. K. D. Malviya was the principal. He was also the chemistry teacher. In my first year itself, I was doing well in physics, chemistry and mathematics. But he said my English was poor. There are anecdotes in my memory, as to how I have missed discoveries by not writing down novel ideas on a few occasions. I have done reasonably well in my scientific career, but I think I

would have done much better, if I could have acquired better writing skill as well. Mr. Malviya asked me to have a tutor for English in my 11th standard. I found a tutor – Prof. Stephens, who was the warden of the hostel where I was living. Then that summer I got jaundice and then typhoid and became very ill. And then after that in the 12th, I stopped the tuitions and concentrated on my science studies. I remember he asked me to read Earl Stanley Gardener's book.

IC: Perry Mason.

GS: Sorry, no. It was a well known author from England, one of his books had short 4-6 page essays. There was this chapter on gentlemen.

IC: Okay. Is this Essay of Elia by Charles Lamb?

GS: I don't remember. But Charles Lamb name is not familiar to me. Maybe the name will come to me. Anyway, this chapter was on 'Gentlemen', who would wake up , have his morning tea, then break fast**,** then go around the village and say hello to every body, then lunch, afternoon nap, and in the evening again go around. By night he gets very tired, even though he did not do any work!. A lot of my cousins were like that, being *zamindars*. They were all 'gentlemen'**.** Let me go back. In 1944, my father had done speculative trade of Silver: *Satta* and the price of silver heavily decreased as Germany surrendered. And then the trades came to collect the money. Immediately, my grandfather got executed partition of the family, with my mother and four brothers on one side and my father was on the other side. Hence, I became a *Zamindar* at the age of 15 or so! The 200 acre farm

belonged to us four brothers and mother, apart from other properties. So that's the childhood.

IC: I wanted to ask you one thing - in school you were saying that the teachers had already noticed that you had interest in science. So are there any other scientific influences that early in your life?

GS: I remember that science in those days was rather simple. '*Ghada thanda kyun hota hai , ya pani thanda kyun hota hai.'* All practical kind of things they used to teach at those times.

IC: What you have done in demonstrations?

GS: There were good laboratory demonstrations at that time. But the books were relatively simple. I should get hold of the high school science books of those years. Why can't we simplify our textbooks? The present books may be okay for big cities but when you go to rural areas or semi-urban towns and the not so dedicated teachers, you have to simplify.

In the 11-12th standard, I remember our Christian College was next to the River Yamuna. Our lab was just 100 m away from the Jamuna River , which was very beautiful. The Yamuna River then had lots of water because it was close to the sangam with the river Ganges. So the Jamuna River before the Sangam was a rather vast lake. I learnt swimming there. When I went to learn swimming, there was a fellow called Jawahar. He said, 'You have to answer one question. If you answer it correctly then only I will take you otherwise not.' He asked me which animal does not know how to swim from

its childhood. So I named various animals. He said, '*woah bhi swim karta hai*.' Cat, dogs they all know how to swim. Then he answered it was only man and donkeys!. While I was talking he threw me into the water, and then he jumped himself to save me.

IC: And you learnt slowly?

GS: I learnt his way of swimming. But I got systematic training, years later at Stanford.

IC: So you learnt finally in Stanford.

GS: Yes systematic teaching. Floating, how to hold the breath. So I swam in the Yamuna and the swimming pool in Allahabad. One could see Anand Bhawan from that swimming pool. Actually I swam a lot because I was a sick child. Swimming is a good exercise and that helped me. I was in Sydney for two years where also I swam a lot.

IC: Coming back to your college, you continued to do your MSc at Ewing Christian College?

GS: While I was at Ewing Christian College, the atom bomb was exploded in 1945. So I was asked to write in the college magazine: 'What is atom bomb'?' My reaction was that I couldn't possibly write that. But, Dr.Malviya induced me to write. He said collect all the newspapers and write from there. So I wrote my first essay, published in a magazine! Then they made me the Secretary of the Physics Society. In the Allahabad

University, there was a famous scientist, Dr. K S Krishnan, co-author of the paper that resulted in the Nobel Prize to Sir C.V. Raman, when they were at Calcutta. I will talk more and more about Dr Krishnan through the interview. I was asked by Head of the Physics Dept., Professor Sharma, if I remember the name correctly, to go to Krishnan's house and invite him for a lecture. I got on my cycle with a friend, and went to meet Dr. Krishnan. I was very apprehensive about how I was going to talk to him in English. So I had practiced it beforehand. I used to practice things like that. Suppose I was traveling from Allahabad to Moradabad and wanted to ask the Railway Superintendent at the Allahabad Station something, I preferred to talk in English to get a correct answer. And that was all prior practice. I recall these incidents to highlight that spoken English was not the practice even in Colleges in U.P. at that time (perhaps even now).

IC: What was the meeting like?

GS: He said he would be delighted to come to our college. He said our college had a lot of x-ray tubes, fluorescent tubes and he would give a lecture on discharge in tubes. And that was extraordinary. I had never seen neon bulbs. I had never seen anything but the normal light of the lamp. In Thakurdwara I used to study under lanterns. There was no electricity in Thakurdwara. So Krishnan's lecture was a great experience and joy about experimental physics. A year later Dr Krishnan told that the college had good X-ray apparatus. In spite of Malviya and Sharma*ji* no one was using them. So Krishnan got them out of the lab. I remember it was of twenty thousand volts, and Dr. Krishnan asked all students to join your hands and

applied the voltage, assuring us that it won't give us a shock as the current was was very small.

After passing 12th standard (IntermediateExam as it was then known), I joined the Allahabad University. My mother again wanted me to go to Benaras University, because one of our distant cousins (from a well-known family of Benaras) was studying engineering there. And all the time she wanted me to study engineering also.

IC: Why was that?

GS: Because of my *mama*'s success. She was very impressed by my *mama* Krishna Swarup, who became Chief Engineer at Integral Coach Factory (ICF). He was the founder chairman of the ICF in Madras. She used to like him and probably saw what he does.

IC: The expectations you have been telling me about are from your mother's side. What kind of expectations were there from your father's side?

GS: My father left me free like my grandfather, I suppose because he was a free and adventurous man in life.

IC: But your mother would have liked you to be an engineer?

GS: She wanted me to do well in a profession. Because she knew that *zamindari* had been abolished and so she wanted me to get settled somewhere.

IC: And you were the youngest child?

GS: Yes I was the youngest child. I was also weak and sick all the time.

IC: Was she alive when you became a professor?

GS: No she died when I was in Stanford. She went into diabetic coma. But she saw me going to Australia and then to Harvard as a full-time research associate.

IC: So she got some satisfaction.

GS: Yes**.** Going to Harvard as a research associate in 1956 was very prestigious. And everybody must have told her how rare it was.

IC: Coming back to your B.Sc and then your M.Sc.

GS: Professor K.S. Krishnan taught me Electricity and Magnetism in the first year B.Sc.

IC: So maths, physics and chemistry were your subjects.

GS: Imagine today, a TIFR scientist teaching a regular course in a university and a university teacher teaching in an undergraduate college. I remember the year I got selected into the Royal Society and was formally admitted at London, I went to Cambridge looking for the Noble Laureate, Prof. Tony

Hewish. He was not in his room and I was told that he may be in an undergraduate lab; when I opened the door to the basement lab, there he was soldering on a board with two students around him. He was probably 70 years old. I watched for a while to see what he was doing. He was actually soldering. I said, 'Tony you are actually soldering at this age'. He said, 'Yes. You got to do these things to teach young students of Physics to use their hands!'

IC: So K .S Krishnan taught you and did that inspire you to do physics eventually?

GS: Absolutely.

IC: So you felt immediately that this was your subject?

GS: Dr Krishnan had left the University in 1947 to become Director of the newly established, National Physics Laboratory at New Delhi under C.S.I.R. invited by Dr. Shanti Swarup Bhatnagar. There was another famous professor in the Allahabad University, Prof. N. R. Dhar, who was probably not as famous as Krishnan. I enjoyed the Physical Chemistry course by Prof. Dhar and had done well. After my B.Sc., he suggested to me to do M.Sc in Chemistry; but I told him that I could join M.Sc. in Chemistry if there was taught only Physical Chemistry and no Organic Chemistry ,as I found great difficulty in remembering large names of compounds in Organic Chemistry! Shanti Swarup Bhatnagar made K.S. Krishnan the Director of the National Physics Laboratory, which I consider very unfortunate for the Allahabad University as it lost a great teacher that impacted many students. In my view,

Krishnan was not so successful at NPL as it had in built bureaucracy. On Krishnan's 100th birthday, I gave great tribute to Dr Krishnan but I also criticized him for not being bold to ignore the bureaucracy of the C.S.I.R.: he could have taken a cue from Dr. Bhabha.

IC: But it was unusual for someone of his stature to come to an undergraduate college?

GS: No he considered it important. He was training people for their Ph.Ds. There was Singhvi, Bhatia – these were all his creations.

IC: No but he came to the college to give lectures to BSc students?

GS: No, he was a Professor and Head of the Physics Department at the Allahabad University where he taught Physics courses to B.Sc. students. But, Krishnan also gave a lecture in an undergraduate college teaching 11th and 12th classes, if invited. I also do it. Narlikar also goes here and there to teach the students.

IC: It was just a one-off lecture.

GS: That is like if you are invited you go to teach students and inspire them.

IC: And that inspired you.

GS: That is in the 11th and12th standard.

IC: And you came closer to him when you were doing your MSc?

GS: No I was his student only in B.Sc. 1st year. By the time, I was studying for M.Sc degree at Allahabad, he had left as he became Director of the National Physics Lab. at New Delhi. But he used to come for examinations. And of course we used to look up to him in those years. There were all these great men in Allahabad during those years. There was Harivansh rai Bachchan, Gorakh Prasad, Tarachand, Ishwari Prasad and so on. You said you did your PhD in history, can you tell me how do you rate Tarachand and Ishwari Prasad during 1940s compared to other historians?

IC: Oh they are among the top few. Because that was a new effort at that point – to write history in our way, in our languages and not in the way the British were writing.

GS: There were other historians also?

IC: Each region had its own historians. There were some famous 19th century Bengali historians. So people who are looking for the Hindi historians would definitely talk about the ones you were mentioning.

GS: As I recall Dr. Ishwari Prasad was doing research in the medieval period. One of my friends, Vinod Seth,a few years older to me and in the same hostel, was doing Ph.D. under Dr. Ishwari Prasad. When we would go walking in the evening in the nearby Alfred Park, he used to tell me anecdotes of India's medieval history. All that multi discipline influence happens in a University. This is what made me an idealist. These were all

collective influences. This was part of what brought me back to India from Stanford.

IC: So these were all the influences that were around you.

GS: That's why I say the IITs can't make a complete man. They are somewhat failure – the model is just not correct.

IC: Were your science teachers at that point of time talking about the latest developments?

GS: Krishnan would do. His lecturers were not totally standard. There used to be a colloquium once a week and Bhatia would say, '*Govind Swarup, Krishnan saab ne is hafte kya padhaya?'* We had half Hindi and half English. The lectures were in English but still there was quite a bit of Hindi. So you had to get to the board and make sure you knew whatever he had taught. Passing the examination was different. This was showing your knowledge on the board.

IC: What about the library? Did Allahabad University have an excellent library at that time?

GS: There was a good library but with the number of increasing students, it was becoming difficult to borrow advanced text books. In my hostel there was a senior student, S. C Jain, an year older to me, came to my hostel room when I was in second year BSc. and asked, '*BSc ke baad kya karonge.*' I said, *'Ji mien M.Sc. karunga.'* He said, *'woh Library mein jaaonge toh*

kitaab nahi milti hai. Hostel me itne studentsB.Scme hai, to yahan hostel me ek society banate hai. Har ek se paise lanige, kitabe lenge.' So we formed a Physics Society in the P.C. Baneree Hostel, unique for any other hostel and bought advanced Physics books. Right from beginning, S.C. Jain was brilliant but also scheming and enterprising. He became somewhat notorious in the National Physical Laboratory years later when Dr Kitchlu, Director of NPL criticized his promotion by the Diector General of CSIR without consulting him. It became a great controversy. Dr. Chagla, the Mister in charge of CSIR defended his promotion in the Parliament, as a meritorious promotion – like TIFR does meritorious promotions.

During my last days in B.Sc., I went to pay my respects to reputed Prof. Shri Ranjan, who was the botany teacher at the Allahabad University. I was introduced to him by my mother as he was a distant relative on her mother's side. Once in 1944 or so, I was sitting outside in his veranda while waiting for him and started putting ink on my hand with my fountain pen and ink started following upwards. As Dr Shri Ranjan came out of his room, I hid my hand. He said, '*Dikhaon kya kar rahe the, kya kare the?'* I showed him and he told me that is how water goes up the plant – surface tension. From then onwards, with that little incident, he started saying, '*Ye bahut hoshiyar hai.'* After my B.Sc he advised me to go to the Indian Institute of Science to work under C.V. Raman.

IC: Okay, so why didn't you do that?

GS: Dr. Shri Ranjan gave me a letter addressed to Dr. S.S. Bhatnagar requesting him to give me a letter of recommendation to Sir C.V. Raman

that I got by approaching Dr. Bhatnagar at New Delhi. I also got a letter of recommendation from Dr. K.S. Krishnan. Then I traveled for the first time in my life outside U.P. and Delhi, from Delhi to Bombay and then to Bangalore. At 4-5 o'clock early in the morning between Bombay and Pune in July, I saw lots of waterfalls. And I had never seen waterfalls in my life before and was very thrilled.

IC: Where were these waterfalls?

GS: I saw them while traveling from Bombay to Pune. A whole lot of absolutely beautiful waterfalls. Then, the train went to Bangalore. I am going off track as often I do, but still let me continue. I took a *tanga* to the Indian Institute of Science. There were no autos then. After a while Tangawala said, '*chalo aab chai pite hai.'* And the *chai* came in a glass. Those years, in UP we drank in the earthen'*kullar*'on road side. I was surprised and I said to myself , '*Bangalore toh bahut modern hai.'*

At the Indian Institute of Science at Bangalore, I met Prof. C.V. Raman and gave him two letters – Bhatnagar's and Krishnan's. He saw Bhatnagar's letter and without opening it threw it into the wastepaper basket.

IC: What about Krishnan's letter?

GS: About Krishnan's letter he said, 'Since he has written a letter to me recommending you, I don't have to read it!'

IC: Did he talk to you?

GS: He said, 'Krishnan has recommended you, I will take you. No problem. I would like to take you. You have to talk to Dr. Thakkar, who was the Director of the Indian Institute of Science. However, the Institute had decided to admit only B.Sc. honors from that year onwards. Allahabad University gave only a B.Sc. degree and not with honors. I was the best student from Allahabad applying to the Indian Institute of Science with Krishnan's recommendation. But Thakker did not allow me and so I went back to Allahabad and I did my MSc there.

IC: I need to know one thing that is not clear to me and that is how you got Bhatnagar's letter?

GS: Through Dr. Shri Ranjan. He was a famous botanist.

IC: Okay.

GS: Dr**.** Shri Ranjan was a well known botanist. Not as much famous as Birbal Sahani from Lucknow. But his name will be there – Shri Ranjan from Allahabad, Botany professor. So he wrote a letter to Shanti Swarup Bhatnagar. I went to Shri Ranjan's house on every festival.
He would insist. If I didn't go he would say, '*Tum Diwali pe nahi aye the, Moradabad se jab aaye thay toa mere liye mithai nahi lekar aaye thay.'*

IC: So this was your first encounter with Raman?

GS: No. My first encounter with C.V. Raman was at Allahabad. It was at the Science Congress-1948.

IC: So he knew you already? He would have recalled you?

GS: He might have. Before I describe my first meeting with C.V. Raman, Let me go back. My stay at Allahabad during 1944 to 1950 was a great experience. In 1942, there was the great famine of Bengal. As I recall it continued till end of 1944. I was in the hostel, men and women would come begging. And from their speech you could guess that they were from well-educated families. And we gave whatever we could. I also used to subscribe to *Harijan* in which Gandhi Ji used to write often. I remember many incidents of my Allahabad days. Let me describe another interesting one: in Ewing Christian College during 1944-46, some students told my friend Mukund and me, '*Aap log bolte ho ghost nahin hota hain*. Cemetery *me raat bhar raho phir dekhte hai.'* We went and stayed at a cemetery near the river Yamuna up to 1' o'clock or so, we stayed put in spite of cat calls by other students trying to scare us, finally they called us back and they agreed with us that that ghosts do not exist.

Coming back to August 15, 1947, I heard the famous speech of Jawaharlal Nehru 'Freedom at Night' that was also relayed outside the Anand Bhawan where Jawaharlal Nehru was born and grew up. Later in January 1948 the Annual Science Congress took place at the Allahabad University and we heard him again. During the Science Congress, another physics student, who became a brigadier years later, said, 'C V Raman *ko hostel mein lunch pe bulate hai.'* I said*, 'pagal ho gaya hai as who Raj Bhavan mein thera hai*

and how would we would we organize lunch in the hostel. But we found a way and invited C V Raman saying that all Physics students would be there and we would give him pure north Indian meal; he readily agreed.

He came to the hostel and spoke about his background for three hours. Then he looked at our eyes and told us that we can also get Nobel Prize that requires 99% perspiration and 1% inspiration: Edison's quotation. I said to myself that I come from a hot country; perspiration is not a problem but how to get inspiration! At the Science Congress in 1948, a famous geophysicist Professor Sydney Chapman from UK was also present. We also invited for an Indian lunch in a restaurant in Civil Lines and later a trip of the old town and the *sangam*. Sydney Chapman readily agreed and told us that he would be glad to ditch a session at the Science Congress. We went to the old town and walked around. At Sangam, he decided to swim in the middle of Ganges, when he saw interesting turbulence due to the blue water of the River Jamuna meeting the whitish water of Ganges. He told us to take his picture (Chapman was well known for studying turbulence in the magnetosphere of the earth). We told the boatman in Hindi '*Saheb ke pass swimming tank nahi hai'* The Boatman was shocked and said 'Firangi *hamare sangam ko kharab nahi karega.'*. When I met Chapman years later in a Conference, he remembered the incident and said that he missed a picture with the turbulence and him!.

IC: He treated the students?

GS: No. I think he might have insisted but we would have paid, because we invited him for lunch. He asked me as to what do I plan to do after B.Sc.

degree. I told Sydney Chapman that my mother wanted me to become an engineer after B.Sc. She didn't want me to become just a teacher that was generally a case those years. Chapman told us that there would be many new opportunities in India after India's Independence and science as a career could also be quite attractive.

IC: Coming back to your years in Allahabad before you went to National Physical Laboratory, what was the political atmosphere of Allahabad University.

GS: Very lively all through my stay at Allahabad during 1944-50, as Allahabad was one of the active centers during India's fight for independence. Many students from Allahabad became important political leaders in due course, N.D. Tiwari who was a few years senior to me at the University: also V.P. Singh, and Arjun Singh couple of years junior in the Arts and not science stream. I recall an interesting anecdote. While I was in the P.C. Banerjee hostel, my elder brother got admission in the Jain Hostel. N. D. Tiwari who was a few years senior was also staying in that hostel. He and my brother used to teach all the servants and cooks in the night. As I recall my brother told me at that time,' *tumko pata nahi Narendra Tiwari bahut laphanga ha'.*

IC: What about the politics at that time. Was it pro congress?

GS: Yes, mostly Congress. RSS had also strong presence but it did not attract me though some fellow students tried to canvass me.

Session Two **Date: January 18, 2005**

Venue: NCRA, Pune

IC: Prof. Swarup yesterday we had stopped at the end of your MSc. at Allahabad. What prompted you to go to National Physical Laboratory?

GS: Well, I had firstly interacted with Prof K.S. Krishnan during my 11th and 12th, when I invited him to the Ewing Christian College. Later, in the first year B.Sc. class he taught me a course on electricity and magnetism in a very inspiring way. He had large influence on the physics department of the Allahabad University, and close interaction with various teachers and students. He was highly respected not just due to the famous Raman and Krishnan Nobel prize paper of 1928, but also his brilliant teaching and research and for his great simplicity and modesty. Of all the scientists I have met in the world, even to date, perhaps he was the most modest person. He was also quite religious but not the normal religious way. He had great belief in teachings of *gita* and some of the Upnishads.. Of course, he was a great *guru,* so I decided to work under him in the National Physics Laboratory, provided he gave me a job. Immediately after my M.Sc. exam, I took a train from Allahabad to Delhi rather than first going to my home at Moradabad. I also applied to the Tata Institute of Fundamental Research for the position of a research scholar. So then I went to Delhi and approached Prof. Krishnan.

IC: Was it easy to meet him?

GS: Yes, he knew me as he taught me. This was the beginning of NPL, I am talking of 1948. NPL was probably formed in 1946 but the building came up

in 1947. Nehru inaugurated it and said, 'I wish I was a director of the lab'. He said it more than once. So I met Prof. Krishnan - I don't recall whether I had to wait

Krishnan gave me copy of a paper by Bleaney on paramagnetic resonance published in 1948 or 1950 in the Proceedings of the Royal Society. He told me to read that paper and to build up the microwave apparatus using modern electronics. He told me that KrishnaJi at Allahabad had told him that I was good in Electronics. Krishnan told me that NPL has acquired lot of old radar equipment left by British as they left India in 1947 and I should try to use parts of it and construct an apparatus for detecting paramagnetic resonance from certain materials near a wavelength of about 3 cm. (I don't thick whether Bleaney got the Nobel Prize but he was a very well reputed person). I knew a little about magnetic resonance because Krishnan was an expert in it and had published many papers during 1930s.After work under C.V. Raman, he excelled in magnetic resonance research. He became a Fellow of the Royal Society in 1940 and was knighted in 1946. He told me to read that paper and use modern electronics instead of the classical way (with galvanometers light reflected ten times, which Krishnan was doing classical way at Calcutta and at Allahabad in an underground Lab. to amplify the signal. If resonance takes place the signal would be amplified through galvanometers reflected to the wall back here). I asked him as to when should I join. He said, 'tomorrow'. I said, 'No my sister is getting married. I will come immediately afterwards.'

IC: So let me get this clear, he gave you this paper to read and at the same time offered the job.

GS: Yes, he said that I am likely to be selected as a Junior Scientific Assistant and I should apply for the post. Unlike TIFR that recruited research scholars, CSIR only hired only regular staff at that time. I did not go for the interview at TIFR. I joined NPL in July 1950 and started working at NPL, sharing an office room of my old friend S.C. Jain from Allahabad, who had joined NPL a year earlier as a Junior Scientific Assistant. S.C. Jain gave me lot of support. In 1950, the Korea War had taken place. After India's independence, various Departments and Organizations of the Government, including CSIR, had recruited lots of staff. In 1950 the Cabinet put a ban on all new recruitments. After a few months, Dr. Krishnan allotted me a room and I started developing the required microwave equipment, using parts from the old radar equipment such as the Klystron oscillator. I designed and got fabricated microwave cavities etc at the NPL workshop, with work order signed by my friend S,C, Jain! Whenever I went to see Krishnan during the next year, he said, 'No wait, I will talk to Bhatnagar don't worry', I asked 'Shall I apply to TIFR in Bombay?' He said, 'No, don't worry'.

IC: By this time did you hear from Bhatnagar?

GS: No. But I will come back to that. So there were World War II equipments in the basement of National Physical Laboratory. There also was an extraordinary series of books. These were the 28 volumes detailing in depth microwave and electronics techniques that described essential knowledge of the advanced radar equipment that was developed in UK and USA during 1939-48. These books were like the *granthas* or the Vedas of

the radar electronics developed during the World War II. Some of these 28 volumes are still very relevant. So reading these books, using old radar equipment parts and guided by Dr Amarjeet Singh who had joined NPL after being trained abroad, I managed to set up the required equipment for paramagnetic resonance but even today I wonder how.

IC: How long did it take you?

GS: Two years. But then I couldn't get the magnet to demonstrate it. Krishnan could have got it from another lab. but he got too busy with administration. I kept on going to him every few months.

IC: This was 1950.

GS: Yes. It was not possible to go to him every month, even though he never got irritated whenever anyone approached him. He was a very patient, a true teacher. For the whole one year, I did not get even one rupee.

IC: So how did you support yourself?

GS: My father would send money.

IC: But you had a job and you were busy working.

GS: Yes and learning every moment was great.

IC: Were you paid retrospectively?

GS: No. Towards the end of that one year I again saw an advertisement from TIFR. I asked Dr Krishnan if I should apply. But he said, 'No, no. There is a newly created post of the Secretary of the Radio Research Committee of CSIR located at NPL.'

IC: That's why your CV has this post and I was wondering why.

GS: So I tell some people that I started my career as a clerk! So that's the clerk part I am highlighting. The reputed Prof. S.K.Mitra of the Indian Institute of Radio Physics and Electronics of the Calcutta University was the Chairman of the Radio Research Committee of CSIR at that time. CSIR had formed a whole lot of committees in different subjects. These were the research grant committees which exist even today. DST, UGC all have such committees for giving grants. Similarly there was the radio research committee. Many scientists were doing ionosphere experiments during the War. During the War, if the British government in UK wanted to send a radio signal to faraway places, e.g. to Singapore, Philippines, Australia or China, etc, signals were transmitted by reflection from the ionosphere with a hop from India. Even till 1971 there was absolutely no other way. Hence ionospheric research was supported by the British Government in various universities in India, mostly at Allahabad, Banaras, Calcutta and Waltair. The radio research committee supported these projects.

In 1951, Dr. Bhatnagar decided to make Dr. Krishnan in charge of the Radio Research Committee at NPL considering the need to give a fillip to the important field of Electronics. The entire set of files from Calcutta was

transferred to NPL. There was an Assistant at IRPE, Calcutta, named Nan the most disorganized man I have seen in my life. He brought those files and they were all jumbled up. So I started organizing these and that's why I say I became a clerk. There was a room opposite Krishnan's room that was allotted for this purpose. Krishnan told me that the work as Secretary would mostly take only one day a week, and I got Rs 300 for it! This was in 1951 and the research assistantship of TIFR was much more meager. People have told me that Rs 300 was big money in early 1950s but did not remain for long.

In August 1952, Dr. Krishnan had gone to Australia to attend the General Assembly of the International Radio Scientific Union. It was the first major meeting in the subject after the War. The Australian research workers were also developing radar equipment during the World War II. Dr J. L. Pawsey was in charge of this effort in the newly created Radiophysics Division of the C.S.I.R.O. After the war, Pawsey started working in the field of radio astronomy and within a few years Pawsey and others had developed novel antenna and receiver systems and made remarkable discoveries regarding radio emission from the Sun and radio galaxies.

Pawsey was born and educated in Australia and later got his PhD degree in 1935 concerning ionospheric propagation working under Dr. J.A. Ratcliff at Cambridge. Ratcliff was considered the father of ionosphere as he discovered various layers of ionosphere. Pawsey told me in 1955 just before I was returning to India after two years working under him in Australia that he went back to Australia only some years after his Ph.D. degree as he

couldn't get a job in Australia. After his Ph.D., he joined the Research laboratories of E.M.I. Electronics Ltd. in England working on antennas.

IC: Because of the specialization.

GS: Or bureaucracy like in India.

IC: In Australia Dr. Krishnan saw all that equipment and became aware of the new discoveries being made concerning radio waves from Sun and other celestial objects. On his return, he described that in a talk at NPL. I was familiar with the radio research field, thanks to Krishnan giving me a job a year earlier. I could understand the equipment so as I recall I asked Krishnan where I could read about it.

IC: Then what did Krishnan say to you?

GS: He said half the papers in radio astronomy were published in Australian journals, I should read those. I recall that I paid some money - around 4 *anna*, 8 *anna* or even 1 rupee– to keep the library open till late in the evening. Remember I learnt all these tricks from S.C. Jain at Allahabad. Anyway, I read those papers and wished to go to Australia. I already had a scholarship to go to Canada – perhaps to the Heisenberg Institute in Canada.

IC: So what made you decide against it?

GS: Rajkumari Amrit Kaur, the health minister had gone to Canada and changed those scholarships to medical. Then CSIR wrote a letter asking me

to wait. That was a great disappointment and I got fed up with the research. So I appeared for IAS.

IC: So tell me about your preparation for IAS.

GS: I decided to do mathematics, physics and statistics instead of mathematics, physics and chemistry. People said it would be easy to get marks in statistics. I bought a book by Yule and Kendell and read it diligently. It helped me later on also.

IC: You then started reading this book.

GS: And I took English lessons from some fellow in Daryaganj.

IC: And then you sat for the exam?

GS: Yes I appeared for the exam but before the results came I got the Australia fellowship and proceeded to Australia.

IC: How did that fellowship come about?

GS: What happened was that Krishnan recommended me for a scholarship under the Colombo Plan for training in radio astronomy. Meanwhile I kept on working at setting up the apparatus for detecting paramagnetic resonance. The toughest part was frequency feedback and frequency stabilizer: what they call controlled oscillators. Dr. Amarjit Singh gave me encouragement. Dr. S.K. Shrivastava from the Defence Science Lab was also there on the top

floor of N.P.L. Many people said ‘do this’ and ‘do that’ but essentially it was self reading from the books. It was also a challenge and that was the most important thing. At the end I nearly made it work but I needed a magnet.

IC: Yes and you were saying that the magnet was not available.

GS: The magnet was there downstairs. But there was politics in NPL and I don’t know how I succumbed to it. Anyway, I didn’t take my apparatus down. People said if I took it someone else would become the first author and I would lose all the credit. Anyway, I don’t remember why I didn’t but I should have written a technical report at least. NPL was extremely interesting in those years because it was in the limelight. Bhabha would come and fly the balloons from there. Nehru would also come often. The buildings were beautiful, all fully air-conditioned. I couldn’t imagine such buildings and also that a whole building could be air conditioned. So it was very interesting working there. There were many good people. But K. S. Krishnan as a director was not so successful unlike Bhabha.

IC: Why do you say that?

GS: Well Bhatnagar was partly responsible but Krishnan could have rebelled. He had too many divisions that exist even today. Bhatnagar set it up in the model of the National Physical Laboratory in Teddington, England. He wanted to set up modern standards Laboratory in modern India. Krishnan knew as a scientist that building a calibration metre and other things were not enough; you needed to do basic research to attract people. Let me give you an example – Siddhi Sadhan Swarup Agarwal came from Allahabad a

year later. He was always ahead of me in Allahabad but he had typhoid so he had to drop one year. He appeared one year later and he was asked to develop an instrument on Nuclear Magnetic Resonance! One should not be doing too many things.

In March 1953, I left for Australia and my apparatus was put in cold storage. I was working alone and there wasn't even a technical assistant. Of course the workshop was available for making the apparatus. In contrast Bhabha would always make sure you had a group. Sreekantan, Devendra Lal, Yash Pal – all of them joined as students and he supported them with equipments.

IC: Tell me a little bit more about K.S. Krishnan.

GS: The Deputy Director Dr B.S. Mathur controlled everything. Krishnan was a soft-spoken person and perhaps one of the most modest persons I have ever known.

Anyway, have you heard of the Yagi antenna? (I want to know about it) It is a TV antenna – the Yagi-Uda – used in small towns. Uda was invited to do research at NPL for two years during 1955-57. So see the number of things Krishnan was putting his finger into.

IC: It's too much of a range for one man.

GS: Yes. I am sure Bhatnagar was telling him that, 'you can do this and that. We will provide the money.' But Krishnan as a scientist should have known.

I am sure he was in the Atomic Energy Committee. Without him Government of India wouldn't have approved it.

IC: You think the failure was largely due to a lack of concentration of effort?

GS: Yes, I think so. I was invited to speak on the occasion of his hundredth year. As far as I remember there were three others – all ex-NPL directors. I wrote it up including all the criticism. They gave me some deadline but I forgot and they also didn't remind me. But I think I should still publish it. Because it is a nice historical account from a successful student! However, I gave him all the credit for encouraging me, like many others who worked under him. Krishnan was indeed a most remarkable scientist of the last centuary.

Coming back to Krishnan, just because the Birla's were giving land next to BITS Pilani it wasn't necessary for a modern subject like electronics to be moved to a desert.

IC: Was the failure also part of the bureaucracy that existed in CSIR?

GS: Absolutely. Shanti Swarup Bhatnagar.

IC: This was in opposition to TIFR. TIFR's bureaucratic structure was very simple at least during Bhabha's time.

GS: Yes. Yes. Have you read a copy of Bhabha's talk in 1965 at ICSU [International Council of Science]?

IC: Yes I have seen that. Science and the Problem of Development. Now how many students of Krishnan grew independently around him?

GS: There was Gyan Mohan, who went to IIT Kanpur to teach but his name is not known internationally. There was S.C. Jain who wrote a number of well known papers in the Proceedings of the Royal Society with Dr. Krishnan as a co-author. Later, he migrated to Belgium. He was quite a character. There is a book by Dr. Kitchlu about why he resigned as Director of NPL. It was because of differences with the Director-General of NPL regarding the promotion of S.C. Jain. This was the first merit promotion in the bureaucracy. TIFR had merit promotion right from the beginning. The Director-General of CSIR promoted S.C. Jain without consulting the NPL Director.

IC: The reason I am asking this is because Bhabha seemed to have attracted a lot of young people around him who he allowed to grow.

GS: Well, atomic energy was growing in a big way.

IC: No, but if you look at the other scientists that he brought in for instance when you come in or when Siddiqi comes in. There is something about the way in which he encourages group leaders to start building their science. There seems to be something different about that style.

GS: I will come back to Dr. Krishnan when I came back from Australia for a year. (Okay)

Dr. Krishnan appreciated the microwave equipment that I had built. He told me that perhaps in due course we could search for resonance from biological materials. This was nowhere in the literature. He was an extremely kind man. He didn't say anything when I requested him to recommend me for a Colombo Plan Fellowship in Australia to do research in the field of radio astronomy. Pawsey had told him they would be glad to take one of his students. Krishnan was a well-known scientist. Pawsey knew about him. Krishnan had charisma about him. Whatever he said was wise. He was good listener to people and a great classical physicist.

Have you heard of Taffy Bowen? He was part of the British Radar Group. Churchill has mentioned him in his book. Anyway, Taffy Bowen became the Director of the Radio Research Laboratory of Australia after the War. According to T.K. Menon, Shapley came to India in 1948. T.K. Menon was then at Indian Institute of Science. Shapley suggested to him that he should go to Harvard. And that's how he ended up there.

Later the Colombo Plan came and two scholarships were created for radio astronomy and many others for other scientific fields. My application was also forwarded by Krishnan. But Krishnan could not attend the concerned meeting of CSIR. I came to know from my contacts in Delhi. Actually if you knew a life insurance agent in 1950, you could walk into South Block.

IC: So this is what you did?

GS: Yes to find out what was happening to my application. Since Dr. Krishnan did not attend the meeting, two other people were recommended. One was from All India Radio and another R. Parthasarthi from the Kodaikanal observatory.

The selection was sent to the concerned authorities in Australia but Pawsey did not accept it as he expected the name of a student of Krishnan. Correspondence continued till I finally got a Colombo Plan fellowship to go to Australia. I sailed first class on the well known Strathmore passenger ship. People told me that you can't survive abroad, especially in Australia, if you don't eat meat. So I decided I would not eat meat till I landed in Australia.

IC: Which year was this? 1952?

GS: 1953 is when I went but the Colombo Plan probably started in 1951. Many young scientists went to Australia on this fellowship.

IC: And this is the same year that your father gave you the little book.

GS: Yes as I was leaving for Australia.

IC: So tell me about it, what was this book about?

GS: Before I left for Australia I went and spent several days with my father in Moradabad. Although I would sit in front of him but he would keep

writing. In the end he gave me what he had written. He had written the family history and a lot of *updesh*. There was a lot of advice about what to do and what not to do. There were several quotations. I was probably his favourite child.

IC: You were obviously special to him.

GS; My mother said, 'meat *mat khana aur khaoge toh aake batana mat*.' So when I came back I was prepared with the answer. When she enquired, I said, '*aapne toh bola uske bare mein kuch baat nahi karenge*.' She never asked me again, her curiosity was suppressed.

IC: So then your ship took off.

GS: I took a beautiful ship from Bombay to Sydney.

IC: What did you first notice when you got out at Sydney?

GS: When I got out at Sydney, I noticed somebody very familiar. He said, 'I am Dr. Hari Narain: *arre aapne toh mujhe padhaya tha Allahabad University mein.'*

IC: And he was there just like that?

GS: He went there earlier under the Colombo Plan. His subject in Australia was Geophysics. While in Australia, he made a magnetic survey across Australia and got a Ph.D. degree from the University of Sydney. A few years

after his return, he became the founder-director of the National Geophysics Research Institute in Hyderabad. He had a very successful career. He was Govind Narain's younger brother. Govind Narain was well-known among ICS of those years being one of the last serving ICS. Later, he became the Governor of U.P.

IC: So you first met Hari Narain?

GS: Yes and he took charge of me and helped me a lot. He told me that he was staying in a guest house and he would fix me there. I could change if I wanted to later. I stayed there for a year. Later he came to India and got married. They rented a flat in a house close to the famous Bondi Beach. Hari Naraian asked me if I wanted to stay in his flat as a paying guest. I agreed and stayed there for a year courtesy of him and his wife Saroj*ji*

IC: And what was the experience of working in radio astronomy?

GS: Radio astronomy was an extraordinary experience. There is nothing like working in a place where discoveries are taking place every few weeks!. Even in the canteen there were discussions about what new had happened that week. I used to keep asking other students, 'So what's new?'

There were two pioneering papers in 1946 by Pawsey, Ruby-Scott and McCready in *Nature* describing the discovery of solar radio bursts from the Sun and also of a million degree Corona. Pawsey and colleagues used the sea interferometer invented by them which used an array of Yagi antennas used earlier for a radar that were mounted on a cliff at a height above the

Pacific ocean. Radio waves were received by the antenna from the rising Sun and also by those reflected by the sea surface, giving fringes due to interference by varying path lengths as the Sun rose up from the horizon. Soon Pawsey attracted many dynamic persons. Bernie Mills, who was working as a technical officer through the War on radar equipment joined the group. In 1948, W.N. Christiansen also joined after having worked for over 10 years in the Amalgamated Wireless Australasia (AWA) 'where he developed ways to make it harder for the enemy to eavesdrop on Australia's radio links with its far-flung allies during WWII'. As I remember John Bolton was a radar officer on the British ship that entered the Bay of Tokyo along with 9 American ships, soon after the surrender of Japan. Later the ship stopped at Sydney on its way back from Tokyo to England. Pawsey came to know about it and he invited Bolton to join CSIRO [Australia's Commonwealth Scientific and Industrial Research Organisation]. Around 1948, Paul Wild who was also returning to England joined CSIRO; soon he made many discoveries regarding radio bursts from the Sun using ingenious equipment developed by him. I consider him as the father of modern solar radio astronomy. Using the above mentioned sea interferometer Bolton discovered that the very strong radio source observed by Reber a dozen years ago towards the constellation Cygnus A was a compact radio source and likely to be very distant. Soon he also discovered many other discrete celestial radio sources for the first time. Observations made by Baade and Minkowski in 1952 using the Mt. Palomar optical telescope indicated that Cygnus A had a redshift of 0.07 and thus much farther than any other galaxy observed at that time.

IC: After you went there?

GS: No I was in NPL. I went to Australia only in ’53. Somebody suggested we could get equipment from Australia under Colombo Plan. Maybe I thought I could do reflection from the ground, without realizing that salty sea is a much better reflector of radio waves.

When I reached Australia, the first question Pawsey asked me was, ‘most Indians want to do theory, so what is it that you want to do?’ I said I enjoyed doing experiments. He asked Steve Smerd to become my guide to teach radio astronomy. Smerd took me to a little room, where all the reprints of Australian papers were available, and gave me a set of about 25 papers and told me that those were almost half of all papers published in the field of radio astronomy across the world! He asked me to read them and if I had any questions I should write on the margins. I remember I had already learnt how to write on the margins. Smerd was a tough taskmaster but he okayed me. After a few weeks, Pawsy decided that I should work three months each with Mills, Christianson, Wild and Bolton.

Under Bernie Mills I designed a phase shifter for the 80 MHz prototype Mills Cross. Next 3 months, I worked under Christiansen and Warburton and calculated Fourier Transform of a several one dimensional scans made at different scanning angles across the Sun at a wavelength of 21 cm that were obtained by them using a 32 element East West and a 16 element North South grating interferometer built by them. Finally, I made a 2 dimensional map of the Quiet Sun at 21 cm. Hard task but very educating.

After that, guided by Paul Wild I along with Jim Roberts built a 45 MHz antenna and a receiver. I recorded radio waves received from the strong source Cygnus A at a location in a trailer about 30 kilometres away and from the town of Dapto, where Paul Wild had built a large antenna and a sweeping spectrum analyzer for recording solar radio bursts. Idea was that if scintillations are caused by ionosphere and if there was ionospheric wind, so he wanted to measure the velocity of the wind of the ionosphere using his solar radio equipment combined with a small antenna far away. I was asked to go to a distant station and set up the equipment in a trailer amongst Aussies in a village. I couldn't even understand their pronunciation and what they were saying. So that was a very interesting experience for me of Australia during 53-'55. They were convicts much earlier. Later they became very cultured. But during my stay, I could hear the women using four letter words in the CSIRO laboratory,

IC: These were secretaries?

GS: They were scientists and secretaries and used such words all the time. You wouldn't expect women to use these in scientific laboratories. They loved Indians and it was really a big cultural experience.

Anyway, Paul Wild then pulled up a paper using a very simple calculation. It was a big lesson for me.

Working with Wild was a big challenge. I was aware that Pawsy was watching. So Wild asked me to make that equipment, which was put in a mobile van and taken 30 miles away from Dapto, where he discovered Type

1, Type 2, Type 3, Type 4 Bursts. Then he thought that at night when the sun was not visible, he would work on ionosphere, by measuring the velocity of ionospheric winds. This was very important to understand in those days.

So I recorded that and brought it to his lab. And he would say, 'Govind, let's interpret it after some beer and dinner.' The first year I had not yet taken to beer but in the second I drank like a fish. All the bars used to close at 6 pm. So at 5 every evening Wild and Smerd would disappear somewhere. One day I decided to follow them. And they were sitting in this bar! They would then come back at 6 pm, discuss for a while and go home.

Anyway, Wild pulled out a plain paper and wrote simple equations analyzing the results. I realized that by simple equations, you could start interpreting data. Basic equations were the most important because you could pull them out anytime. You could use sophisticated theory later.

After Paul Wild, I was asked to work with Bolton. Bolton was building an 85-foot dish for observing radio emission from the centre of our Galaxy that is almost overhead near Sydney. A steerable dish would have been expensive, and therefore he decided to dig a hole in the soft soil some distant away from the sea in the form of a parabolic dish and line it up with chicken wire mesh. It was interesting experiment. He asked me to dig. Now I wasn't good at digging at all. He said, '*Aah* you Indians!' He probably knew that I was an ex-Zamindar's son. Later, I built a 2000 volt DC supply with a high voltage regulation, under the direction of Gordon Stanley of Bolton's team.

After the end of one-year, I and Parthasarathy were to suggest our own project. Christiansen who had built a very interesting grating array for mapping the Sun, decided to go abroad on a sabbatical leave. I was aware of a paper from the group of Martin Ryle at Cambridge, where the authors said there was no limb brightening on the sun at 500 MHz, even though Smerd had predicted it in a detailed paper published by him. Christianson had discovered limb brightening at 21 cm using the grating interferometer and that was something to do with electron density as a function of latitude around the sun. Electron density may not be the same near the pole as the equator. This was important to understand. Hence, I and R. Parthasarathy proposed to convert Christiansen's grating array from its operation at 21cm wavelength (1400 MHz) to 500 MHz.

Pawsey liked the proposal as he did not believe the Cambridge result and also because he was trying to train us as experimentalists. He had already trained John Bolton, Paul Wild and others. He knew that novel apparatus could make great discoveries. He had a love for India.

IC: So you suggested this larger apparatus?

GS: No, we suggested converting the 21cm grating array of 32 numbers of six-foot dishes that Christiansen had built as a 700 feet long grating array at Potts Hill near Sydney to a wavelength of 60 cm (500 MHz). The dishes were all built and installed, transmission lines for connecting the antennas to a central receiver were there. But we had to change dipoles near the focus and retune or match the transmission line. It was a novel interesting transmission line system, which had to be re-soldered using longer matching

lines with thick soldering iron, 250 watt. We had to do all that with no technical assistance. Then we had to make the receiver work at 500 MHz and then take data, analyze and publish results. We finally published a paper stating that there was the Sun had a limb brightening at 500 MHz.

On his return from France a year later when I and Parthasarathy were still in Australia, Christianson decided to build a cross type solar radio bigger telescope using larger dishes. Mills was making the large Mills Cross for observing distant celestial radio sources that were called radio galaxies. Mills concept of making a pencil beam antenna became famous. All over the world, many crosses and Tee shaped antennas have been made.

I asked Pawsey what was going to be done with the 6 ft. dishes. He said maybe we could take them to India.

So, I wrote a letter to Dr. Krishnan, at N.P.L. Krishnan replied saying Krishnan (1955) replied: “I agree with you that we should be able to do some radio astronomy work even with the meager resources available”. Pawsey also may have written to Krishnan. I also put a whole lot of drawings and parts of receiver in a big wooden box also to be sent to India. Soon, the Australians packed up everything

IC: At the level of government, was it difficult to get material like this?

GS: No. Krishnan was keen to get the equipment. CSIRO wanted India to bear the transport cost of seven hundred pounds. But, Dr. Bhatnagar, Director General of the C.S.I.R. noted that while thanking CSIRO, they may

be requested to also bear transport charges. That went to bureaucratic correspondence for over a year!

I returned to India after working in a very rich research environment and joined NPL as a Junior Scientific Officer. I was keen to start work in radio astronomy at NPL straight away.

IC: Which year did you come back from Australia?

GS: In 1955.
Let me go back a bit. While we were converting this equipment we were required to solder using a thick iron and a torch the matching strips on the 9 mm copper transmission of the branching system. At the end of the day we would make tea. It was June and therefore winter time in Australia. Parthsarathi would fetch some extra water to wash his face and hands. I was writing notes one day when I heard a faint voice, 'Govind, Govind.' I thought he must be asking for another bucket. I went to look but couldn't see him anywhere. Some 400 feet away there was a tap but he wouldn't go there. He would always take water in his bucket, he enjoyed doing that. I couldn't see him but could hear his faint voice. I remember he would always wear this Salvation Army dress. Anyway, I saw he had slipped into the lake. I told him to take a deep breath and was about to give him a hand. But he was pointing at the cable. So I tied a coaxial cable (RG8) and pulled him out. Some people have the story wrong and they say I fell down and some other Indian saved me. This was because my name was known.

All his clothes were wet and so I found him a new set using worker's spare set in the cabin. I told him to take his wet clothes to the guest house for drying. He refused because he didn't want to tell anyone how his clothes got wet. So he tied them to a tree outside his hut and left them to dry. I pointed out that next morning other big people would come and enquire what happened. He said he would come early. So next morning the watchman came before him and wondered that someone had drowned. It was the headline in the *Sydney Morning Herald*.

Once I went into the Christianson lab to find a pair of shoes being heated. They could have caught fire. Apparently they were Sarthi's shoes and because they were making a *'char mer'* sound, he had put water in them and was heating them! He was really a lovely man.

Anyway, so Sarthi suggested we return together in the cargo boat in July. My father was in Calcutta. So we traveled in the cargo boat from Sydney to Melbourne, to Adelaide and Perth, then passed through Indonesia, stopped for a week in Singapore, a week in Madras, and then to Calcutta. We were supposed to come back in February but we thought of an experiment. I proposed that with our 500 MHz grating array, we might see reflection of the Crab Nebula on the corona of the Sun during its approach. The Colombo Plan Australian authorities allowed our extension, as Pawsey wrote that it was an important experiment that two Indians were doing. So we stayed on for a few more months.

IC: So what happened to the seven hundred pounds?

GS: Well, so I came to NPL and started working but dishes seemed a distant dream. Six months later, one day my great friend S.C. Jain said, 'Govind why don't you go to America?' I had told him that some groups in USA had started work in radio astronomy and including work in the field of solar radio astronomy at Harvard, but said I didn't want to apply. But he typed a letter to Harvard, saying it was up to me whether I wanted to go or not but what was the harm in writing the letter. Lo and behold! I got a letter from Dr Menzel, the Director of the Harvard College Observatory. He offered me the position of research associate at $5200. I got married in June 1956 and with my wife went to Harvard in August 1956.

IC: But what happened about seven hundred pounds?

GS: Correspondence must have continued after I left. I understand that Australians paid and sent the equipments – so I was told. In 1957, Dr M.R. Kundu joined N.P.L after his Ph.D. degree from France where he worked with a 3 cm solar radio interferometer. Dr.A.P. Mitra had earlier joined N.P.L. as Secretay of the Radio Rsearch Committee Mitra had gone to Australia two years before me under the Colombo Plan. He was Professor S.K. Mitra's student from Calcutta. He returned to NPL from the US ahead of me. Dr K.S. Krishnan refers to him, in his letter to me that Dr. Mitra was also keen to start radio astronomy work at N.P.L. When I returned I didn't want to work under A.P. Mitra. Then there was one Swami*ji*, who was in Germany through the War. I joined his group. Krishnan had collected a lot of people at NPL. The 32 dishes were received later by NPL, perhaps in late 1957. N.V.G. Sarma and M.N. Joshi, who joined me at TIFR in 1964, had joined NPL. Sarma joined NPL after M.Sc degree from the University at

Waltair, where there was a reputed ionospheric group, and Joshi after obtaining M.Sc. degree from the University at Dharwar. Before going to Harvard, I had already started building the complex ocal oscillator. Sarma completed that receiver system at 500 MHz.

IC: Let me get this right - you came back to NPL before going to Harvard and then you get married?

GS: After I joined NPL with the 32 nos. of 6 ft dishes not in sight, *I wrote* to several groups in USA. John Bolton who had joined Caltech to build a large radio telescope wrote saying that they were still building the equipment. I got an immediate reply from Harvard and the third place was Michigan, which also sent me an encouraging reply. These were the three places where radio astronomy was being done in a big way.

So I got an offer from Harvard. Probably they knew about me as I was already a solar radio astronomer. Then I got married to Bina, who was daughter of the reputed economist, Dr. L.C. Jain. I understand that he enquired about me from K.S. Krishnan and apparently K.S. Krishnan spoke well of me!

IC: Before we end today, I have one more question. You spoke a bit about your experience in Australia, but what was the social experience of living there?

GS: Absolutely nice. I can tell you that there were not many Indian students and wherever we went, common Australians welcomed us. They had heard

about India but didn't know much about it. Suppose I was traveling on a tram – they would ask if I was from some island. When I would say that no I was from India, they would be very happy and conversation would start from there. Often, I was invited to astronomer's home, and they would be extremely friendly. There were some little children to whom I would say that I used to go to school on elephants. This was half a truth because I did once went to the school on an elephant that was bought by my father to be able to cross a small river during monsoon between Thakurdwara, where we lived and the Kashipur railaway station, for taking a train to the city of Moradabad . I spent two years in Australia, seven years in the United States and a year in Holland and beyond doubt Australia was the friendliest place.

IC: There was no racism?

GS: No. I never had any racist experience. There was a programme put together by Indian students where I danced in *Chitrangada*, organized by Mrs. Sen, the wife of the Indian Counselor at Sydney.

IC: Tagore's *Chitrangada*? And what were you *Arjuna*?

GS: No I was just a village boy. It was in the Sydney Hall. The pictures appeared in the newspapers.

General Cariappa, who became the first Chief Commander of the Indian Army after the independence, was later appointed as the High Commissioner of India in Australia, during the second year I was there. He got into great controversy as he criticized the white Australia policy and opined that

Australians should welcome migration of Indian soldiers who fought with Australian and English solders in the World War II. Sometime later, Gen. Cariappa, on his way from Canberra to Melbourne, started cleaning war memorials at various towns on the way. He would do this early in the morning and nobody knew for some time as to who had done it. Some journalist followed the trail and found him doing it and Gen. Cariappa became a hero in all newspapers.

IC: But it was mainly a white policy?

GS: Yes total white policy till 1960 or so. Even if I had made a great discovery there, they wouldn't have hired me as a scientist in Australia at that time. It was a total white policy.

IC: So policy wise it was not friendly to foreigners.

GS: They didn't want immigration from Asia, although some enterprising Indians went to Australia and set up businesses. A business man, named Patel from Gujarat set up a shop in early 1950s to sell Usha sewing machines imported from Calcutta. They were much cheaper and so he made a lot of money. Some other Gujarati were selling something else. They were well accepted. Indian Consulate and General Cariappa encouraged trade relations between Australia and India. Then the Colombo Plan supported nearly hundred Indian students during 1950s.

IC: And this is the place where you overcame some of the barriers, like those of food and drink?

GS: Yes. Paul Wild once asked me, 'Govind, when you came to Australia did you have a cultural shock?' I said, 'I don't understand what you mean by cultural shock, I did find it interesting.' Years later when I first went to Nigeria, I got out of the airport and my host was not there. There were riots taking place so he couldn't appear. A fellow at immigration asked me, 'Do you have some dollars? I will get you past quickly.' I was wise enough and didn't take out any dollars. As I get out there were these big fellows telling me they would take me to a hotel. And suddenly I was afraid.

IC: So you feel that was your cultural shock in Nigeria?

GS: I had seen several blacks in the United States but in Nigeria I was afraid of them. When foreigners come to Bombay airport they probably feel the same.

Session Three **Date: 19th January 2005**

IC: Prof. Swarup, yesterday we spoke about your return from Australia to India and to NPL. Today I would like to take you back briefly to that because we are mainly going to talk about Harvard and Stanford. Now there are these letters from Krishnan that you had given me where you had sent him the proposal about the study of solar radiations using a 2010 feet long 32 elements and to operate simultaneously at 60 cm and 1.83m wavelength. This is when the dishes were sent?

GS: Pawsy had agreed to let me take them to India. But once I got them to India, I could simply not repeat what was being done in Australia. So it occurred to me that there was an opportunity at lower frequencies. I recall there was no interferometer in 1965 around 150 MHz with sufficient resolution for observing the Sun. Hence I proposed making the dishes to work simultaneously at two frequencies near 500 MHz and 500/3 MHz by using suitably resonant dipoles, by switching diodes. This way we could locate the sources of radio bursts from the Sun. Paul Wild had been observing the dynamic spectra but there was no inferometers at that time for routinely locating the solar radio bursts. French radio astronomers had started building solar interferometers at metre wavelengths. We could have been one of the pioneers in the field. I was in NPL for a few years earlier. So it was not difficult for me to visualize that one can actually build large low cost arrays using labour available in India.

IC: But were you also sure of money?

GS: I didn't need much money for it. Dishes were coming from there, receiver was there and I told you I had a lot of drawings. Some components were required but those were vacuum tubes which were available in India in those years.

IC: But what about the cost of labour?

GS: NPL was well endowed.

IC: So there was no problem.

GS: I have already I told you, that NPL had fully air-conditioned buildings. Besides I was doing technology. The Australians were also doing that. Apart from radio astronomy they also had a division of technology. And that was something that always inspired me – that one should do something for the country.

The inspiring speeches by Nehru, C.V. Raman and others really mattered. It was an era where you wanted to do things. It was not just about pure science and I knew I would do much better if I did science and technology. All kinds of antennae were there in Australia. During World War II, radiation laboratory series had collaboration with CSIRO and the entire set of technical reports was there. I had picked up lot of techniques. Money didn't seem to be too much of a problem and the basic idea was to prove yourself.

But then I always wondered why Bhatnagar hesitated to pay 700 pounds. In 1955-56 there was no question of foreign exchange crisis. And recently, only about 2 years ago, somebody sent me an article on Blackett in India published in the Economist. It was a long article on how Blackett was responsible in advising Nehru about CSIR. It seems he advised that CSIR should concentrate more on technical aspects rather than basic research. So probably he saw that lot of scientists were just doing basic research instead of giving technical help to the country. I do not know what inspired him to make that comment which is there in that recommendation. Blackett was also one of the chief scientific officers of the English World War II effort. Now I have no idea whether Bhatnagar thought that radio astronomy was not the right thing for NPL. The basic point is that I waited for six months.

There was no letter from NPL asking for the dishes. So I decided to go and ask Krishnan about it. Krishnan said, 'yes, yes we are getting them'.

IC: And you had a very modest budget here – Rs 10, 000?

GS: It was Rs 10, 000 in '55. If you consider the 10% inflation per year, it comes to 5 lakh today.

IC: But even Krishnan seems to recognize that even with the meagre resources available in the laboratory, you could do this work.

GS: Yes, this is what he said. He was the Director and of course a very famous man.

IC: He also thought that A.P. Mitra was someone who would be able to work with you on this?

GS: A.P.Mitra was 2 years my senior. But A.P. Mitra was an ionosphere physicist; his heart was in ionosphere and not in astronomy in general. He became very famous in the field of ionosphere. He also became the Director-general of CSIR after becoming the Director of NPL.

IC: So what did you do soon after you came back to NPL?

GS: I started working on a variety of things. Apart from the dishes I had an idea to build dipolar arrays. So I started working on certain technical things regarding dipolar rays. Using the drawings I made a receiver. What was to

come from Australia would not have done the job for these dual frequencies. So I started building the receiver in the workshop. Then like I told you before when I left for Harvard, Sarma and Joshi joined to build the receiver. So when I first came to NPL I was hoping the dishes would come soon, even if I went for a year or so.

IC: By the end of 1955, you were already writing to Washington and other places?

GS: When for 4-5 months nothing was happening, I told you S.C. Jain typed the letter. He said if the dishes come you don't have to go but at least you would be able to say that Harvard offered you a job and you didn't go.

IC: But you also wrote to Carnegie Institute?

GS: So then I wrote to Harvard, Carnegie Institute and I think to John Bolton. Bolton was invited by Caltech for building a brand new instrument because radio galaxies had been discovered. Caltech had Mount Palomar but they invited Bolton to build three, 90-foot dishes inferometer. Harvard was doing solar radio astronomy. They had done 21 cm discovery so that was a well-known group. Michigan was also doing solar radio astronomy. Did I write to Carnegie Institute? I don't remember very well.

IC: Yes you did. In fact there is a letter from M.A. Tuve, saying, 'I am personally very impressed by your qualification. I shall, in the next few weeks, make a number of inquiries looking towards the possibility of

providing a suitable fellowship or other appointment in order to make it possible for you to come to this country.'

GS: Tuve was one of the greatest geophysicists of United States. He was the director of Carnegie Institute of Washington. Bernie Burke, who discovered radiation from Jupiter, was Tuve's student.

IC: But before the Carnegie offer really came, you heard from Harvard?

GS: Yes. And Harvard in those years was as well-known in India as Cambridge. There was nothing like Harvard and Cambridge. Even today these are the two greatest institutions of science.

IC: As a research associate you got an annual salary of $5200.

GS: I will come back to that money a bit later. I got married in June 1956 and in late July-early August straight away proceeded to join Harvard. I stopped in London on the way. My friend Siddhi Sadhan Swarup Agarwal had got a fellowship to work at the Imperial College in London. And whatever nuclear magnetic resonance apparatus he had set in NPL was also put in cold storage. NPL didn't know how to put together work by people.

So I stopped in London and of course saw the Buckingham Palace and Madame Tussaud's museum. I still remember Madame Tussaud's – I think they had Nehru there. What was remarkable about London was the blackishness of the buildings – they all looked so old. It was 1956 and they had not yet rebuilt from the ravages of war.

IC: Yes it was still suffering from the effects of the World War II and post-depression.

GS: But then I went 20 years later, I was totally surprised. That was the effect of oil. The wealth of western countries is in oil more than anything else.

IC: So your wife went with you to London?

GS: Yes. We stopped in London and then ended up in Boston, where Harvard is located. The radio observatory for which I was given an offer was in Texas. Harold Ewen, who discovered the 21 cm radiation from our Galaxy in 1951 along with his Professor Edward Purcell, later founded a firm and was making receivers for science as well as the military. Military was very big money in those years and the Air Force needed those very sensitive receivers. His name was Ewen.

Alan Maxwell from New Zealand who got Ph.D. at Jodrell Bank was invited to be the Director of this new Radio Astronomy Station at Fort Davis in Texas. Menzel thought that they should do solar radio astronomy research at Harvard. So whether Maxwell suggested or Menzell himself decided but they bought this receiver and an antenna. They bought a 28 foot dish which was amongst the third largest in the world at that time. It was built by D.S. Kennedy.There was already a student at Fort Davis from Stanford, Sam Goldstein, a student of Bracewell. Bracewell told him to go and work with Maxwell. So they needed somebody with experience of solar radio

astronomy which I had in Australia and also technical know-how because the complex receiver had to be maintained and data analyzed. And so I landed in Boston. The famous Bart Bok and his wife Priscilla met us at the airport. We were to fly to Fort Davis a few days later, so Bok insisted that we see many famous spots in Boston including where the tea imported by Englishmen was thrown by Americans as the first American revolt!

IC: Oh the Boston Tea Party.

GS: My wife was very tired and she doesn't like these things about history. But I enjoyed. He took us to the 65 foot dish which Harvard had built. It was an experience because this extremely well-known man was taking us around the whole day.

Then three-four days later we flew to El Paso from where we took the small Dakota plane to a place called Marfa, next to Fort Davis. One thing I remember when we went from El Paso to Marfa - the Dakota plane suddenly went down by tens of feet. It was very hot there and my wife was wondering where I had brought her. Anyway, we landed at Marfa and Maxwell came and took us to Fort Davis.

Fort Davis is a town of 700 people. They chose it because it is surrounded by hills and they needed a relatively radio quiet zone. Besides there is also located the McDonald observatory near Fort Davis. At that time McDonald observatory had an 80 inch-90 inch optical telescope, which was the third largest in the world.

So at Harvard Radio Astronomy Station, I started systematic work. Now Maxwell and Sam Goldstein didn't get along well. Maxwell was a very strict disciplinarian and I consider him one of my *gurus* because he taught me many things. He also taught me driving. So within 2-3 weeks I bought a car, which was from some old lady who had hardly driven 10,000 miles over 10 years. It was a Plymouth car. There was no problem learning driving in this town of 700 people.

Anyway at work I started systematically documenting, taking from the experience of my education at Allahabad and work at Australia.

IC: So this was the time when you were beginning it together in a systematic way?

GS: The spectra of solar radio bursts were recorded daily on 100 feet films. So we wrote to Kodak to get high dynamic range. The normal films give you only black to white 300 to 1 or something like that. We got 700 to 1. Today 10,000 to 1 is possible in films. But the normal films are not more than 1000 to 1. We developed ourselves and Maxwell was very good at getting these things done. The receiver system was in a trailer because the building was under construction. Once we opened the trailer on a Sunday and there was a rattlesnake inside! Of course I was used to the Cobra from my childhood but this rattlesnake really scared me away.

Soon my wife went to complete her education – she hadn't completed her BA. If I had stayed in India a few more months and a year, she would have, but now she still had one year of her BA left. Then in December Maxwell

went to New Zealand for his vacation to be with his mother. He was the only son and was extremely devoted to her. He never married. As I was systematically recording I noticed in the record on the film showed a very strange burst. I called it Type U burst. Maxwell came and said, 'Well, look this is our first paper. We should write it as Maxwell and Swarup.' He was nowhere around when I had done this work. But the paper became Maxwell and Swarup, partly because he offered to change $5200 to $5600 and money was important. He also said he would recommend me to Harvard and to Menzel. Of course later he also sent me to the American Astronomical Society to make a presentation and at Harvard. They were all extremely interested to know what makes these electrons going out of the Sun to turn back. We did some more work together that resulted in other papers.

Now, coming back to Goldstein, I remember one day in the lab. building, he and Maxwell were about to hit each other. I had to intervene and resolve the issue. Goldstein used to have the craziest ideas in science 'Can I discover this? Can I discover that? Can I do that?' So around December when I had discovered this Type U burst, my wife was unhappy living in this small town. There were only 10 or so white American families. The rest were Mexicans and few were blacks.

IC: So, you were the only Indians in that town?

GS: Of course. Once we decided to buy a sofa. We had an oldish sofa from the same old lady from whom we had bought the car. Maxwell had recommended us highly to her and she was very helpful to me and my wife. So we went to Marfa to look at a new sofa. My wife didn't want to come out

of the car because it was very hot. The proprietor just wouldn't turn his attention to me. So I decided to get my wife in, she was wearing a colourful saree. I said, 'Bina come I'll show you something.' And the moment she came, all the attention was turned towards her. People were very interested in people from India.

There were huge cattle ranches all around Fort Davis. George Bush's ranch is quite far from there. The churches organized get-togethers and we would be invited. We would always be the centre of attraction. Once a man asked me where I was educated. When I said Ewing Christian College, he asked me to repeat the name. His next question was, 'Is that a Presbyterian church?' I said it was a Christian church. I had read about the Catholics and Protestants but I didn't know about the Presbyterians. Then he called his wife and said, 'Look at this man. I pay $100 to the Ewing Christian College every year and you say I am wasting my money. But look this young man he has come to Harvard!

IC: And you met them at a church fete?

GS: Yes at a church fete.

IC: Quite interesting.

GS: He was absolutely delighted. I realize now that we should have kept in touch with all those people. You know, there were newspaper articles about us, the Indian couple; I have copies. Apart from news about the telescope, there was a whole column about my wife and what she does.

Anyway, after six months Sam Goldstein said, 'Govind, you must work for a Ph.D.'.

IC: I see a letter here from Pawsey saying, 'I think you would do well to work for a PhD'. This is dated 8 Feb, 1957 and so shortly after almost a year of working there.

GS: No. Six months. I went there in August and in December I had discovered the Type U burst, which left a mark not only on Maxwell but also on Harvard. So Goldstein said, 'Govind, you must do your PhD. You know so much'.

IC: Did it not strike you to do a PhD before?

GS: No.

IC: You just felt you wanted to do research.

GS: Yes. I don't think John Bolton and Paul Wild had PhDs. Perhaps Christiansen didn't have a PhD degree. Pawsy of course had a PhD.

IC: And you were already a radio astronomer.

GS: Anything we worked on, any result we published was great news to the well-known astronomers who had slogged through their careers.

IC: So PhD didn't matter at that time.

GS: Yes, at that time.

IC: What made you think of it?

GS: Sam Goldstein. And of course I knew that if I returned to India then getting a PhD would be the most important thing. It was also clear that I was not going to settle in the United States. The very thought never came to my mind. So after Goldstein suggested, I applied to Stanford, Harvard and Caltech.

IC: In fact from Harvard you have a letter written by Cecilia Payne-Gaposchkin asking you about your courses.

GS: I didn't want to do pure astrophysics - learning about classical stars. I was a physicist and had already done a lot of radio astronomy. So I wanted a joint degree of physics and astronomy. They always wanted a joint student so Cecilia offered. Bolton also wrote from Caltech saying if I was interested in their work, I could apply. But then a letter from Pawsy was like an eye opener for me. Can you read what exactly he wrote?

IC: He writes, 'I also agree with you trying to get a combination of astronomy, electronics and physics. If you are returning to India, I should recommend you to place great emphasis on electronics which is a key to open many doors'. So I think you had already told him what you wanted to do.

GS: Using that knowledge the Australians were making many discoveries. Everything they touched, a new thing was discovered. Anything they observed using the simple minded receiver was a discovery. I had already recognized that when I wanted to start radio astronomy in NPL. So Pawsy wrote that and I highly valued his opinion. And I already knew Bracewell. How I came to know Bracewell is another interesting story.

IC: Tell me about it.

GS: I was working with Christianson in Australia. He had made a lot of one dimensional maps of the sun. He scanned sun beams like this and then he scanned in some other direction because it was a one dimensional array. So I was doing this with him when Bracewell walked into the room. It was lunch time. And Bracewell said, 'Govind, don't you play cricket?' These people were making discoveries without much work and they would never work at lunchtime. But they had the direction, they had the opportunity and they were focused. The focus is very important. So they went to play cricket and after the beer in the evening and dinner they probably thought and the next day were back to work. They didn't waste time in their offices. So when he asked me about cricket, I said, 'A tennis ball had hit my eyes many years ago and so I don't play ball games.' Then he asked me, 'But do you know Sanskrit?' I knew a little. He then wanted to go for a walk. He just wanted to talk. I think he was not so interested in playing cricket so he just wanted to have company. So this is how I came to know Bracewell.

IC: So this was in Australia and later on you met him again?

GS: Yes. I wrote to him and Stanford offered me a position. Goldstein had told me everything about Stanford. While in India I had never heard of Stanford. I knew of only MIT, Harvard and Caltech.

So precisely one year after that, I drove to Stanford. We also carried the sofa we had bought. My wife was going to be a student also and the Stanford salary was lower than $5200. There was an international conference of International Radio Scientific Union in Boulder and we drove in a U-haul truck with our sofa and other things.

Goldstein said, 'Govind, no problem why are you afraid?' Sam was in some sense my best friend. He passed away some years ago. His wife is still there, though she is battling cancer. Bina exchanges letters with her even today. So we drove and stopped in Boulder. We went to the Garden of Rocks. We were around 1000 odd people in the conference at lunch when suddenly there were people coming on horses. Bina got very worried about what was happening. I said, 'just watch.' Some were getting worried but not others. It was all part of the show. They were white people who had dressed up as Red Indians. Then we drove from Boulder to California. It was a difficult journey crossing the desert. When I joined Stanford, Bracewell told me I had to sit for a qualifying examination. I saw the papers and what kind of questions they asked and decided to do it six months later. He said, 'You are a physicist. You will have an advantage and so must appear for the examination.' So, of course I bought some first year engineering books, some of them are still with me. In India we know how to pass examinations. So I did well and in three years and four months I finished my PhD.

IC: What did your PhD involve?

GS: Solar microwave emission. Now Bracewell was building a Mills-Cross type interferometer. I can show you the photographs later, but I will describe it to you briefly. There were 32 dishes of 10 feet diameter working at microwaves at 3 GHz. Christianson was building at 21 cm wavelength, which is about 1.4 GHz. Bracewell decided to get a high resolution on the Sun and he built a high quality instrument, an American quality instrument. I shouldn't say this in front of the Australians. So what Bracewell was doing became my project and I mastered it. He had six seven students. Roger Colvin had built the receiver. But when the paper was to be published, he came to me and said, 'we will publish it as Bracewell and Swarup.' There were other students working with him for a longer time. But I really made the instrument work.

As you know in the first year as a graduate student you have to work half the time on a project as either a teaching or a research assistant. I chose to be the research assistant. But I should tell you more about my course work before I tell about the research I did. This will also include Stanford. So should I talk about the life in Stanford first or the teaching?

IC: You can talk about your teaching and then come to social and political aspects.

GS: I took the transistor electronics course by Linville. The most important thing was that I had also been working. I knew what to learn and what not to

learn. The transistors were new to me. I was working on vacuum tubes at N.P.L. and Australia, and even the Fort Davis receivers had no transistors. I bought a small radio at Marfa Alpine for my wife which had a transistor for the audio amplifier. So already in ’55 you couldn’t learn much from the literature that was there. I took electromagnetic theory and a few other courses.

Prof. John Linville. was one of the six people who worked with Shockley for the discovery of transistor at Bell Labs. In his lectures, he highlighted physics part more than the electronics. The electronics courses in India are in contrast to that. The practical in his course at Stanford were taught by taking a set of transistors and measuring every parameter of it very carefully, and then enquire as to up to what higher frequencies they will work or not work. There are radio waves, there are capacitors and inductors, and there are wires, so measure everything very carefully. And if you don’t get theoretical performance, explain why you didn’t get it, whether the measurements are not right or theories are not right, what is the problem.

IC: And compared to that you were doing the physics of it first.

GS: Yes. Similarly there was the control system course. And of course there were the classical courses like higher level Algebraic Calculus and other things. I had read books by Churchill and also by Fred Terman. Terman was known as the father of electronics and had written five-six books by then. I could read it like a bible, like a novel, [it was] so beautifully written.

So that was the first year. Then in the second year I took a course on microwaves. This was in the Ginzton's Lab. On Tuesday he would describe the experiments to be done. There were 10-12 people and he would give 2-3 topics. Then on Thursday he would conduct the lab – from 1pm to 10 pm in the night. Dinner time was from 6-7 pm. You had to be prepared with what measurements you were going to do, the introduction, and the purpose. I did many experiments with him but one of the experiments I remember was measuring velocity of light. He would suggest various experiments and the students could chose or he would assign. There were around three different microwave cavities for measuring the velocity of light. And so you measure resonance in large cavities so that losses are very low. You can then measure the frequency of resonance very accurately. If losses are not there, ticks are sharper and you can measure what is the frequency of resonance. We did all that and then at 10 pm the books were taken and compared. Then 10-11 pm would be discussions. That's the kind of teaching there.

Now, Bob Helliwell taught me ionosphere. I was only in my second year when Sputnik happened in 1957. So some student phoned to say that Bob Helliwell has heard that Russians have launched a satellite which was not thought as possible. We did not know what frequency it was transmitting but Helliwell thought it must be in the HF radio frequency range used for radio broad casting at 15 to 20MHz. All students of Heliwell including me took our radios and climbed a large hill on campus. Sometime around 2 AM or 3 AM we got the news that a student had heard beep beep. And Bob Helliwell said yes this must be the signal. And we all got together and Bob said, 'Remember our class is at 9'clock in the morning.' And we went to sleep at

2 or 3 am in the morning after having found the first signal by anybody in U.S.A.

IC: You were talking about the Sputnik. This was the time which was quite interesting in America and in Europe because of the Cold War. There was this kind of competition between Russia and America and you were in the middle of it.

GS: It was also in education. This was not only in astronomy but also in science in general, politics in general. We'll talk about it later. So I was doing electromagnetic theory. Halliwell once asked, 'If the satellite is in the ionosphere, what will be a good frequency for transmission?' He was giving a current problem to the students because he knew that it was a matter of days before someone would phone him and say that America wanted to launch a satellite.

IC: So did you solve that problem?

GS: Yes I think I did. I did try to figure it out. I don't remember whether my answer was the best. But I certainly had the right approach. But these are the kind of things that give you confidence.

For the Stanford Cross, Bracewell asked us to I was working on the complex waveguide system connecting all the dishes. When the first map was made, it seemed totally wrong, there seemed to be a strong radio emission well away from the sun towards the pole. And Ron said, 'Govind, may be it is possible to get radio emission over North Pole of the Sun, why not?' I said,

'No, it was not possible, I think something is wrong.' I convinced him that there was something wrong and he said, 'Well, maybe you have made a phase error in matching the waveguide system.' I said, 'Look Ron, I may be absent minded in my behaviour but if I was absent minded I wouldn't have passed the qualifying exam.' Anyway Bracewell told me to phase it again. And we did it over a period of six weeks. I did that day and night and again the map was wrong. I concluded to Ron, 'Look, I think the antenna positions are not right.' He said, 'Not possible, we hired this well experienced man and he had done the survey and I saw what he was doing.' I told him I would repeat this for the third time provided he checked the antenna positions. So we jointly agreed. But again another 4-6 weeks were going to be lost. Then I got an idea: if I send a signal from the centre to a far away antenna, I will get an echo back. So, if you are on a hill and if you are surrounded by hills and shout to your wife or child, 'Oh!! I am here', there may be other voices but you recognize the voice because you know from which direction the voice is coming. I had already learnt dipoles and ionosphere with Helliwell. So, I placed a little fluorescent tube in front of the waveguide horn near the focus of the 10 ft. dishes, modulated the microwave signal sent from the centre of the waveguide system with a1000 Hz signal and got an echo back, 700 feet away. Thus, I could modulate an echo and measure the phase. This was the well known Swarup and Yang paper. It was the fastest paper I had written – in three weeks time. I am known very well for this contribution.

IC: And this was before your PhD?

GS: This was part of my PhD. Then daily radio maps of the Sun came like flying saucers. I made daily two dimensional maps of the solar radio

emission at a wavelength of 9.1 cm. They provided valuable information. And within a year I had written my thesis. At that time, I started applying to several places in USA. When I was working on microwave measurements, one of my teammates was from Hughes electronics, freshly formed around Stanford. They were trying to build antennas for space. He introduced me to his boss and I was returning to India and I thought maybe when I come back I should forget radio astronomy and do satellite antenna technology. I also applied to various places including the National Radio Astronomy Observatory. Yet I returned to India and I will tell you about how I was invited by Bell Labs.

I was invited by Bell Labs. In Feb. 1962, Dr Hogg from Bell Labs visited the Stanford Cross Antenna for solar observations where I was working. I demonstrated to him our round trip phase measurement scheme. He told me that they have constructed a large horn that has measured excess temperature towards the sky than expected by them, and asked can I use this technique for checking losses in the horn?' My son was to be born in a few months and Bhabha had already offered me the job. Hence I did not go to Bell Labs. Three years later, Penzias and Wilson made fresh measurements of the excess temperature that was considered by others as Cosmic Background Temperature and brought them the Nobel Prize.

IC: So that didn't go through?

GS: I regret about that all the time but on the other hand if I had not come back the idea of the Ooty telescope would not have taken place. Sometimes you have to be at right time at right place.

Session Four **9th February 2005**

IC: Prof. Swarup last time we stopped with your PhD at Stanford. Today I want to talk about your last year at Stanford and how the offer of assistant professorship came about.

GS: During my course work at Stanford I started making maps of the sun. I invented a technique that has been used all over the world. I found that the intensity of power from sun spots was higher at the wavelength of 9.1 cm where these maps were made for the first time in the world compared to in Australia or Japan. That surprised me very much. Then while I was writing my thesis, a Japanese fellow named Kakinuma came. I had been using his data also. Anyway, he said he had also been wondering the same and he was not sure. But putting his data and mine together he said we should then invent a new theory. So we talked about a new model suggesting that the magnetic field is higher near the sun spots and goes into corona. That provides the resonance. Kakinuma and I wrote a paper on that and it is one of my most important and quoted publications. The model is used today not only for solar radio emission but for explaining the radio emission from flare stars as well. That work was not published by end 1960 but it was written down. Then of course my phasing paper was there. Prof. George Swenson, who was the chairman of the electrical engineering department at Illinois, was building a big radio telescope. He invited me to be an assistant professor at Illinois. I also wrote to the National Radio Astronomy Observatory in USA. I was invited by NRAO to give a talk. They offered me a job saying 50 per cent would be as a friend of the astronomer, that means helping and

doing the dirty work, and 50 per cent would be for my own research. I told them if I were to join I would like to concentrate building an interferometer that did not exist at all at NRAO at that time. Soon after that Dr Heeschen, Director of NRAO wrote me a letter saying they had talked to National Science Foundation and 'if I was to join NRAO I would be the leader of radio interferometry there'. That was the greatest offer that a young man could get.

So with the offer from Illinois and NRAO, Bracewell got Stanford to make me an assistant professor. Stanford normally doesn't make such an offer to their graduate students.

IC: So you feel it was the competition that forced Stanford to make the offer?

GS: Well not exactly competition. They realized they could find what I had done was useful. So I joined. Of course my wife loved California. Later at Stanford I missed an opportunity.

IC: What was that?

GS: The chairman of the department called me and said I should give an undergraduate course on digital engineering. And I told him that I had not studied that. He said from what he knew of me I should have no problems. Unfortunately not many students applied and I didn't get a chance to teach that course. When I returned to India and built the Ooty Radio Telescope, I couldn't help building a digital unit group at Ooty till a long time later. And Ooty Radio Telescope suffered because of that.

Then soon the Kakinuma-Swarup paper was done and I was wondering what to do next. So I automated the maps. But after I finished I was wondering what else to do. So I and a student Picken doubled the resolution of the Stanford east west interferometer by putting two more antennas. This was published by Picken and Swarup. This led to a paper just before I left Stanford by Swarup, Thompson and Bracewell. We observed the strong radio source, Cygnus A and showed that it didn't consist of two but three components, which tells the age of the source. When observations were made by an American scientist 25 years later using the VLA, he quoted that Swarup, Thompson and Bracewell were the first ones to show that extragalactic sources have three components.

I should tell you about two other important things. I became assistant professor at Stanford in January 1961. I had submitted my thesis in December 1960. Then a year later Dr Hogg came from Bell Labs and the tradition in Stanford was that the youngest new entrant has to show him around. So I was showing him various facilities of radio science, the first radar echo to Venus. Then I brought him to our laboratory and showed him how we made the maps using Swarup and Yang technique. He said they had a horn that produced excess temperature. He asked me if I would go and help them calibrate. I considered for a while, but my son was to be born and my wife was not happy to let me go for a month. So I didn't go. Already Bhabha had made the offer and I had accepted that immediately and seriously started thinking about coming back to India.

There was another very important milestone which I missed in my career. As I was making these maps of the sun, I noticed that the radio emission from one pole of the sun was less than the other pole. That intrigued me and I

looked whether this was due to prominences, which we know are cooler portions of the sun. I tried to correlate it but could not. Then I wondered whether it was due to some problem with the antenna cross couplings. One day it just occurred to me that I could go from one to two dimensional. I described this to Bracewell while going on a picnic. He said, 'Govind, this is nonsense. It's not possible.' So when I went to office on Monday morning Bracewell summoned me to his office. He had cut with scissors and made a three-dimensional model. He said, 'your model works.' We talked for a while and he told me to write a paper. I told him that I couldn't write a paper unless I had an application in mind. So I went to the library and looked for Snedden's book. I was told that it had been stolen. Bracewell and published a paper 5 years later and got more than 700 citations. I came back to India and decided to pursue the idea here. I gave the problem to my student Ramesh Sinha who still remembers that. He was a very bright fellow but was always jumping from one subject to another. Maybe we will talk about Ramesh Sinha some other time.

I should now talk about returning to India.

IC: Yes. Just to stay with this a little more. Did you see yourself then as part of the larger legacy of science?

GS: Not at all. I was a student from a small town. My father had lost all the money and I had to prove myself. I was not easy at all. My command over English was poor. So there was a communication problem.

IC: So around the beginning of the 60s itself you seem to have started thinking about coming back to India. Can you recount that?

GS: When I went to the US, the idea was always to return to India. I had worked at NPL for four years, two years in Australia. Being from a family of farmers I knew I could build a radio telescope in an innovative way at a low cost. When I returned from Australia, I had the idea of building the telescope in Pilani. I went to Harvard, came back. Then decided to be a graduate student and went to Stanford. Then Pawsy and Christianson passed through Stanford on a visit of the US from Australia. They asked me what I wanted to do next. I told them I wanted to go back to India. They encouraged me by writing long letters. While Stanford did not say they would get me the visa, Illinois definitely said they would convert my J1 visa to a regular working visa.

Bracewell said, 'Govind, you can be second rate in somebody else's field or first rate in your own field.' I will never forget that phrase. I have often said this to young men. So therefore I started correspondence. In 1961 there was an international conference in Berkeley.

IC: Yes. But before we come to that, I see a letter here dated 26th December 1960. It's written to you by J.L. Pawsey. He writes, 'I think your idea of getting together a group of Indians like yourself to start a new radio astronomy laboratory is very sound. To my mind it is much the most promising possibility of making India play an effective role in radio astronomy.' So you had already thought about this in the 60s. So when exactly did this thought come to your head?

GS: Right from the beginning.

IC: That you could build a group?

GS: I didn't know for sure that I could get a group going. I could see along with Kundu, Kuchu Menon and T. Krishnan.

IC: You people met in 1961?

GS: I think I corresponded with Kundu in 1959.

IC: And you had proposed this to Kundu?

GS: We must have talked and discussed about what we were going to do after going back to India. I must have suggested that perhaps we could get together. Because I didn't want to come back alone. I wanted a world-class team to come back. We were like kings there in the US.

I remember in 1959, the great Minkowski and Baade were the two most famous professors at Caltech. So Minkowski gave a set of lectures on galaxies at Berkeley. We used to drive all the way from Stanford to Berkeley to attend his lectures. I wanted to ask him why he wasn't talking about how the universe was formed. But I did not ask the question. So I wanted to say that this was the kind of thing we could do.

IC: As the Astronomical Union conference comes to a close in August 1961, there are two things I wanted to ask. One is that you were already thinking of meeting and defining your proposal.

GS: Yes we were kind of getting together various things. We never really had a proposal.

IC: So there was T.K. Menon, you, Mukul Kundu and T. Krishnan. But probably T. Krishnan did not make it?

GS: Pawsey arranged for him to come. We were already in the US and doing good work.

IC: So four of you met there?

GS: Yes.

IC: There was something else here. You seem to be also trying to get an IAU resolution about radio astronomy. What was that about?

GS: To say that if a group of Indians went to a developing country it was a good idea. Probably the IAU resolution took place but I have to check that.

IC: In the correspondence it says that 'this may not be possible but still we should go ahead even if there is no resolution.'

GS: Yes IAU may not have come up with a resolution for that. Several years later both IAU and URSI passed a resolution supporting the proposal by me and Okoye for the giant equatorial radio telescope that I would describe later.

At this point two things happened. I had probably already written about my desire to return to India after my PhD to several persons in India. I do recall that Dr K.G. Ramanathan, C.V. Raman's former student if I recall correctly, and the senior Professor next to Dr. Sarabhai wrote a letter to me making an offer.

T. Krishnan came from a very illustrious family of IAS and senior Govt. of India officials from Tamil Nadu. He had made a visit to India in 1960 and he talked to several persons for support for a radio telescope array in India. He also approached a senior member of the TVS family as they were in some

way connected to his family. They told him if he was set it up at Madurai, they would give him Rs 5 lakh to start radio astronomy and electronics there. He wrote to me and I readily agreed to join in a letter to him as I was keen to return. T. Krishnan belonged to a famous south Indian family and he was able to walk into any office. During his visit, he also talked to the Director General of CSIR, who promised to give additional Rs. 5 lakh.

So with Rs 10 lakh, I knew the whole thing was possible. Once you prove yourself more money comes.

All four of us had worked in top-class places. Kochu Menon had done his PhD from Harvard. Kundu had done his PhD in France under Steinberg in the Paris Observatory, where Jean-François Denisse was the leading radio astronomer Dennis later became the chairman of CNES, the Space Agency in France. We decided our referees – Pawsey, Dennis, Martin Ryle, Bart Bok, Shapley,and Oort. Referees' comments are likely to be in a confidential file at TIFR. Bart Bok wrote a letter whose copy is with me. Four of us sent a copy of our proposal to form a radio astronomy group in India. We wrote to Bhabha, DG CSIR, DG Metrological Observatories that was also operating the reputed Kodaikanal Observatory, to Dr. Kothari, Chairman UGC and to Dr. Sarabhai Director Physical Observatory at Ahmadabad.

IC: Were you sending the same proposal to these three or four places?

GS: Yes identical. We made no changes. The points were that we wanted to come back together, wanted to firstly use the 6 ft. dishes with NPL and set up a solar radio telescope, at the same time start working with a large Mills

Cross using dipole arrays which didn't require very much expense. We also considered that work at low frequencies was important.

IC: Then it was just Bhabha who sent that telegram to you?

GS: CSIR wrote that a resolution had been approved that it should support any group wanting to return to India.

IC: But in a letter to Kochu Menon you write, 'Let us wait till we hear more from Bhabha.' Kochu's letter came after Bhabha had already expressed some interest in the meeting with him in Washington D.C.

GS: Yes. Within a few months after receiving our proposal, Bhabha made us an offer. He sent a cable to all four of us on 20 January 1962: "We have decided to form a radio astronomy group stop letter follows with offer…." . He wrote to me on 3 April 1962: "If your group fulfills the expectations we have of it, this could lead to some very much bigger equipment and work in radio astronomy in India than we see foresee at present." He also wrote to me to return at an early date as the scientific progress of India required urgency. If he had not put pressure, I might have written about the one-dimensional to two-dimensional paper that I conceived without going to Fourier Transform. I often wondered about that. if I had stayed a little longer at Stanford, I would have gone to the Bell Labs to work on the Hogg horn to find the cause of the excess temperature reported in 1961, using the round trip measurement that I had conceived in 1959; 3 years later discovered Penzias and Wilson discovered the cosmic microwave background radiation and soon got a Noble Prize

IC: It seems to me that when the correspondence with Bhabha started**,** it was mainly with T.K. Menon.

GS: That was because we decided as a group that one person should correspond. We thought it would be good for Indian beauracracy too if a single person wrote. But we wrote very clearly that all of us must have the same position.

IC: And yet the same position was not given.

GS: Yes and this created a stir in the group. T. Krishnan dropped out and I think we would have achieved much more if he was with us. He was a doer. He went back to Madras and achieved a lot. T. Krishnan was an aggressive man in his early years. He toned down later thanks to his wife.

So I accepted the job straightaway. Kundu did not accept it because he thought it was wrong.

IC: There are letters in the Archives written by Kochu Menon to MGK Menon and Bhabha, talking about your seniority in the group and your publications.

GS: I may have told Kochu that Kundu was upset but he did not see the exact sentences that Mukul wrote to me. I did not pass the letter to him.

IC: But he was trying to plead on behalf of you.

GS: Kochu could have written a letter to Bhabha saying he couldn't accept the offer as a Reader and everyone should be given the same position. But he did not do that. This is my personal opinion. I have never told this to Kochu. But Mukul feels very strongly that Kochu did not play a fair game as we

trusted him. Remember Pawsey wrote to me that I be the leader of the group and there would always be someone to balance it.

IC: So you wanted to do your work while someone else dealt with all this.

GS: No. No. I wanted this fast. I knew that radio astronomy was making big discoveries all the time and we should do this fast.

IC: So you wanted to start off the work.

GS: Yes. If we had returned together we could have achieved a greater recognition. Later Ooty RadioTelescope had an accident and it may not have taken place. I was running the Ooty Radio Telescope and also helped in construction of the Satellite Earth Station at ARVI, thanks to Sarabhai and Indira Gandhi. Added to that I was guiding a dozen students towards Ph. D. degree. I was trying to build a group – we had seen Harvard, Stanford, the best of the world. We had been to every observatory at that time. It was a different era.

IC: So coming back to the offer from Bhabha, you responded immediately. You were also working on papers and had teaching commitments.

GS: Bracewell then cut down on my teaching commitments. Bhabha's offer had come and Bracewell wanted me to concentrate on work at the Stanford Cross. He wanted me to concentrate on building automatic maps of the sun. I changed the gears of the electric typewriter. Originally there was standard spacing and it would not make a circular map as apparent diameter of the Sun during the year due to changing distance between the earth and the Sun but the sun is circular. I realized that if the gear ratio was changed, the carriage return would change the spacing and it makes something close to a

circle. So the automation of the Stanford radio graph was done by me in 1962.

IC: So you were trying to wind up that work. There is something else which is not self-explanatory. There is a letter from T.K. Menon in September ’62 which refers to a proposal to the Research Corporation in New York for a grant of $10,000.

GS: As we returned to India foreign exchange would become a problem. Since Kochu, was at NRAO, I requested him to pursue it. I also suggested that if we made a cylinder in the ground we could do millimeter astronomy. But Kochu said it would get too expensive. He didn’t realize that I had done 3cm centimeter wave work at NPL, even before I went to Australia and worked at 9.1 cm for the Stanford Cross. These things could have been done in India. One didn’t need to import so much, except certain components. Anyway, Kochu suggested we should write to the Research Corporation.

IC: And Bhabha was supposed to follow it up?

GS: I don’t remember that.

IC: Did this grant come through?

GS: No, I don’t recall that.

IC: Okay. Now let’s talk about your coming back.

GS: I had come back by cargo boat from Australia just to see Indonesia and Singapore. This cargo journey was an extraordinary experience and it’s still vivid in my mind.

I planned to return to India in December 1962 by the Queen Elizabeth-I which was to make its round the world journey from England through the Panama Canal, to San Francisco, Tokyo, Australia to Bombay and back to U.K. It was a luxury liner and it was its maiden trip. I could afford it having worked for several years in U.S.A. So we booked it but a month or two before that trip, I came to know that it had caught fire. So now I booked a flight to return via Europe. I had already made a commitment to Bhabha and Bracewell told me, 'This man means business, you better go.' So we came back with our 8-month old son and two and a half year old daughter. We flew to England and went around Europe by train. We went to Bologna where a parabolic cylinder for a radio telescope was being built and Bracewell had told me to take a look at that. Then we went to Naples and took a boat to India.

Now earlier, Merl Tuve wrote me a letter saying they were contemplating making an offer. He was the Director of the Carnegie Institute of Washington and one of the most famous geophysicists of the last century. He told me they were building 21m diameter antenna to be sent to Argentina to explore HI in the southern sky and wondered whether we could request it to be sent to India instead. I told him no I was going back to my own country to do independent research.

IC: I had one more question. This is a letter written to Mukul Kundu on September 10th, 1962. You are looking at four alternatives you gave him, one of them being that you wanted a part of the budget to do your own work to prove yourself.

GS: Shall I take this file and read it before tomorrow? See in 1962, I had accepted Bhabha's letter. You must remind me about what was Bhabha's offer next day.

IC: I am just trying to understand whether you were looking into the possibility of doing something independently?

GS: You can be working on a common project and yet be working on something else. Its all part of the same group – in TIFR everyone does that. This is academic freedom. It was very clear that most of them wanted to publish using existing telescopes. But I wanted to build things for unsolved problems in Pawsey's style. He told me not to follow fashionable ideas but work on unfashionable ideas which you might think are good for science. If you succeed very well, otherwise spend a small amount of time and go to something else.

IC: So we can stop here today.

Session Five **Date: 10th February 2005**

IC: Prof. Swarup, can you tell me a little more about what you saw in Bologna. Why did you go there?

GS: Well I first went to Holland to meet Prof. Oort, because they were building what was known at that time as the Benelux cross. It was a 2 km long cross antenna. And I heard that they were modifying the design and some of the Australians were there. I had a fascinating time with Prof. Oort, he encouraged me very much. Since I was a solar radio astronomer, it was

very important to go to Paris. Of course I was with my wife, so we had to go to Paris and see the great museums and all that. Fortunately a friend of ours from Stanford was in Paris.

IC: What's his name?

GS: Ramesh Bharat. An absolutely bright yet crazy and interesting fellow. At that time he was dating a Swiss girl, whom he married later. At that time they were living together.

IC: He was an astronomer?

GS: He was an electrical engineer who after Stanford lived for a while across the bay in San Francisco. And then he joined Raytheon and it's quite a story.

IC: So you spent time with him.

GS: Yes we spent time with him. He showed me around and we also went to Moulin Rouge.

IC: Okay, you managed with the children. They were very small, weren't they?

GS: Well, I don't remember what exactly we did with them. Perhaps we got somebody to baby-sit, thanks to Ramesh Bharat or Monique Pick. Monique was a solar physicist there – much younger than me. So I spent time in Solar Radio Astronomy of France and then went to Switzerland for a few days of holiday and then to Bologna.

IC: What were you doing in Bologna?

GS: Bologna had plans to build a radio telescope. Bracewell thought I should see it. And since I was passing through Europe anyway, I thought it was a good idea. There I met Prof. Marcello Ceccarelli, a very dynamic and ambitious scientist as well with lots of wits. He was a Cosmic Ray physicist, who had decided to initiate radio astronomy at the University of Bologna. And he decided to make a large parabolic cylindrical radio telescope steerable only in declination near Bologna. It still exists. The Ooty telescope is made of a similar design except that we built it on a hill slope as I will tell later. I saw photo of one frame which had been built in Milan. I didn't see the frame, but I saw the photograph. Of course we were very well looked after there and I don't have time to describe the hospitality of Italians. So the basic point I want to make is that I became aware of a modern parabolic cylinder. The first use of a parabolic cylinder in radio astronomy was by Martin Ryle in Cambridge, which I described to you. He did a famous survey which created a controversy with Hoyle. And then of course there was smaller parabolic cylinders built in Armenia under the late Dr. Ambrutsimian, who started designing few smaller versions of Ryle's radio telescope. Cheapish versions, by cheapish I mean low cost. And the Bologna Cross was based on a cylinder.

IC: Now tell me one thing in all the papers that you have given me, from 1960 onwards when you were planning to return to India, there are various jottings at various points about what work you can do in India. Now did Bologna influence the way you would be working in Kalyan?

GS: No, not at all. Unless there is a definitive scientific experiment we don't want to copy anybody. You can't also just propose something out of the blue. So there has to be some scientific thing. But you slowly become aware

of the cutting edge of technology and you become aware of what you can put together. In 1963, Bracewell, I and Seeger had already published a paper in Nature, titled "Future large Telescopes" using an array of parallel 1 km long parabolic cylinders located like a venetian blind. Mills Cross in Australia was also being constructed using parabolic cylinders. So I saw its design at Bologna and was quite impressed about their project. After Bologna, we made the fascinating journey back to India, through the Suez Canal and Aden. At Aden I bought a shirt and was quite happy about it. But when I opened it on the ship, the sleeves were missing. (Laughter)

IC: So you really got gypped.

GS: I got aware of the Arabian way of life on the way to Bombay. It was a good lesson. I landed up in TIFR on 30th March and talked to MGK Menon.

IC: You landed in Bombay on 30th March and went to TIFR the next day. Now where did you stay?

GS: My wife's uncle was the General Manager of the Times of India. He was quite an extraordinary man. He also started Eve's weekly and Filmfare. But I don't want to talk about him – his lifestyle was not consistent with my lifestyle.

IC: You stayed in his house?

GS: Yes, we stayed with him. When I went to see Prof. Menon next day, I asked him when could I join. He said tomorrow and I realized it was the 1st of April.

IC: Did you join?

GS: No I did not want to join on April's fool day! I joined on the 2nd of April. Then I went home to Delhi. My father-in-law had passed away, soon after we left for the US in 1956. Then my mother also passed away within weeks of my joining Stanford in 1957. And those were not the years when you could fly back. I think I paid Rs. 3200 for the airfare when we went to the US. It was Rs. 4 to a dollar and the one way fare was 800 dollars. Today also it is 700 dollars. So the air fares haven't changed. Let us say they have become 20 times cheaper because India has been on an average of 10% inflation per year in the last 50 years. So that's why so many people can travel today.

So I joined on 2nd April and went to Delhi to meet family.

IC: But on that day did you meet anybody else apart from Prof. Menon?

GS: I don't really recall. But then we were very keen to go to Delhi and meet Bina's mother.

IC: What was you first impression of it when you walked in?

GS: It seemed like a great place. Of course I had seen the National Physical Laboratory, but TIFR on the sea side was something else. Some years later I used to say 'India begins next to here.'

IC: And what about Bhabha, you did not see him?

GS: No I don't recall meeting him at that time.

IC: So how did your family react on seeing you?

GS: Of course they were very delighted to see their two grand children. One was 9 months old and the other was a bit less than three. And my father decided to go to our home town Thakurdwara where I was born.

IC: With all of you?

GS: My father said we may not ever go back there. Bina had never seen the house. So we went to Thakurdwara, our home town. I was delighted to be back. But you know the area had a lot of malaria.

IC: So that hadn't changed.

GS: There was DDT everywhere in around the rooms. I was very impressed and mosquitoes were less. But in spite of that my daughter caught a heavy infection. Not infection, but an allergy. And we had to rush to Moradabad and the doctors gave some anti allergic and she was okay. But my wife thought she was going to die. And she was very angry with me because I took them there.

Anyway we came back soon to TIFR. What was extraordinary was that Prof. Menon wrote a letter to me while I was at Stanford saying I would need equipment when I returned. I had made a list of equipments which we might require. I was amazed that all that had been ordered before I returned!

Today if you place a purchase order in TIFR it will be minimum 6 months time before the purchase order will be placed. After Prof. Menon's speech on the occasion of JRD Tata's centenary, we were asked to say something about him. I remember I recounted this incident. I said he was a proactive dean and I hope the present dean was also proactive. And everybody said 'Yes, yes. Prof. Kurup the present dean is different.'

So within a week or so of coming to TIFR, I asked the workshop to make a 20 or 30 foot dish to place it along with the Kalyan Radio Telescope. This was not in the proposal made to Bhabha but as I was coming to India I saw the 30 foot dishes at Stanford, which had gun turrets. Bracewell had got these almost free from somewhere. So I talked to Dr. Allardice, in charge of administration division, the absolutely remarkable man next to Bhabha, both in TIFR and Atomic Energy. He was an ICS, married to a Maharashtrian lady if I remember right. Anyway, he said no problem and he took me within a month to a great big yard in Sewri full of scrap guns! He told me he could get me these. So it was wonderful. The mechanical aspect was the problem, but today if we got gun turrets tomorrow we could build bigger dishes. The gun turrets were probably overkill for a 30-foot dish.

I recall that years later when I had gone to the TIFR workshop on a Dusshera day, the supervisor who had made this first frame had one frame tied to the workshop. He said it was his first job and he was not going to remove it. That was the TIFR workshop in those years. It was absolutely delightful to see the enthusiasm.

IC: What was his name?

GS: Mehta, if I remember right. Isloor will know better. And then of course there was the drawing section. Isloor has a photograph of a 20-foot dish being assembled. I would like to have that photograph as early as possible.

IC: I think he will be bringing it because we are putting some of it for display.

GS: Okay, so by May end Bhabha had written a letter to the Director General of CSIR to get the dishes.

IC: These were the dishes that had come from Australia?

GS: Yes. They were all sitting in NPL in their original Australian packing.

IC: So Bhabha acquired them for you?

GS: Yes Bhabha wrote a letter.

IC: And it came quite soon?

GS: Yes I think it came soon. Probably around mid 1963.

IC: That's quite soon because you joined in April.

GS: Of course. If Bhabha wrote to Director General of CSIR, they had to come straight away. It probably took a longer time because Sharma and Joshi were a bit hesitant. They wanted to set it up in Delhi. And they had gone abroad and it was a while before they returned. But I was anyway designing 30-foot dishes.

Now, a great big new story begins. Outstanding! It was the first week of June 1963 and I was sitting in the library of TIFR. I took the journal *Nature* from the racks. Some of the new results in the new field of radio astronomy were published in *Nature* promptly. So in that issue there were two papers. One on the occultation of a radio source called 3C273 - 3C-third catalogue of Cambridge. It was number 273, which Martin Ryle had catalogued - a strong source in the sky called 3C273. And occultation means accurate position and one dimensional structure. Using its accurate position, Baade

and Minkowski had observed it with the 5m diametre Mount Palomar optical telescope of Caltech. And they identified it with a radio source. There was this young man named Martin Schmidt, who worked in the total tradition of astrophysics in Holland, had a Sinclair calculator as I recall. 3C273 was a quasi stellar radio source that looked like a star. It was point like. But its line emissions didn't meet any of the known elements. It suddenly came upon Schmidt that the ratio looked familiar to him. These were the three lines of hydrogen. These were the first Bohr orbit, the second Bohr orbit and the third Bohr orbit - H alpha, H beta, H gamma. So it was obvious that this source was located at a redshift of 0 17, which means at that time - the most distant radio source in this universe.

There is another story here. As I was returning from Australia in 1955, there was some occultation of radio sources taking place. There was a scientist from Cambridge, who wanted to put a receiver together to see the occultation in some galactic radio source, as I recall Orion Nebula. He told me, 'Govind, such and such source is getting occulted in Madras also. So as you return to NPL why don't you go to Madras and see this occultation.' But as I returned to NPL nobody was there to give me any support. Shanti Swarup Bhatnagar could not foresee that we were not only astronomers but radio geniuses first! Radio astronomers were well ahead in any engineering establishment including Bell Labs.

So coming back, I knew the controversy over Big Bang. In 1958 or so Martin Ryle had catalogued over 300 sources and found that weaker strength sources were more numerous, supporting the Big Bang model in contrast to the Steady State model of the Universe. So sitting in the library itself I got the design of the Ooty telescope within an hour.

IC: And this happened from reading the paper on occultation?

GS: Yes and my background and keeping up with the field.

IC: Whose paper was this?

GS: There were two papers. One by Cyril Hazard and the other by Martin Schmidt.

IC: So this was in 1963?

GS: June 1963.

IC: So the Ooty telescope idea came and you went immediately to Menon?

GS: Yes. So he asked me what a parabolic cylindrical looked like and I told him. I had Bologna in mind, so I told him that it was one transmission time tower put on top of another one, and then rotated. He asked me if I knew anything about Kamani. I knew nothing. So he arranged for me to visit the Kamanis in Bombay. They were number one in high power transmission line. I told Menon it was not practical and so we would continue with the Kalyan telescope. Kalyan was not yet there.

IC: So the Ooty idea came before Kalyan?

GS: Well, Kalyan was there in our proposal.

IC: Yes, but you hadn't started.

GS: Yes. And so Menon made a very important point as a scientist. Instead of discouraging, like many people would today, he told me 'If you don't want to build it, why don't you write a paper?' A scientist always loves to

write a paper. So I started working it out and within a month I wrote a proposal for the occultation telescope. Now early August I was going to Tokyo to attend the meeting of the International Radio Scientific Union (URSI), where my good friend Kakinuma of the Kakinuma and Swarup paper invited me for a 3 months stay. Following our work at Stanford, we wanted to see if we could calculate the change of magnetic fields after a large flare in a sunspot from change of microwave emission? People had not used that idea. So he arranged for an Indo-Japanese association grant.

And so I wanted to meet Bhabha to discuss the occultation telescope proposal before the URSI meeting because once I wrote it up, it became very clear that it was a hot project. It was a practical project too. I had met engineers at BARC, or rather Atomic Energy Establishment as it was known then. I had also met the Kamanis.

Martin Ryle, John Bolton and Mills were all attending this conference in Tokyo. This was the first international conference in Japan. The Japanese had already been doing good work in radio astronomy. And who wouldn't want to go to Japan in 1963.

IC: Was this your first meeting with Bhabha?

GS: No, I had already met him when I returned.

IC: I wanted to know about that first meeting.

GS: I don't recall the first meeting, but I recall this meeting very well. I recall the first meeting with MGK Menon with whom I dealt. With Bhabha it was always short meetings. And then may be he attended my colloquium.

IC: Did he ask questions?

GS: Absolutely, he did ask sharp questions.

So about this meeting with Bhabha. Menon said he was very busy and it should be only for 10 or 15 minutes late in the evening. I kept on waiting. He questioned me for an hour or hour and a half. Fortunately, I had thought about it. He asked me things like if you put it on a slope, what will happen? The frame would want to incline with the bearings, would go down. Fortunately I had all the answers. Then he said, 'Go ahead and I will support it.' I asked him if I needed to write a project proposal. I had written a scientific proposal but project proposal requires you to give the budget. He said, 'Young man, don't waste your time. Form a group. When you have formed a group we will approve your project.' So it became very important to form a group.

IC: So at that point of time you were alone?

GS: I was alone. If you see the correspondence 1961–1962, we had identified M.N. Joshi and N.V.G. Sharma for attracting to our radio astronomy group. After receiving encouragement by Dr. Bhabha, I described the idea at the URSI General assembly that was held at Tokyo in August 1963. Everybody supported our proposal. In the meantime NASA wrote to me that they were organizing a 3-day symposium on solar astronomy. They invited me for a full 45-minute talk based on my Stanford work. And so I cut short my Japanese trip. I still regret it.

So I went to United States, talked to Bracewell and gave a talk. I also made a mistake and my diagram was wrong. But everybody was supportive of it. Then I went to Cambridge. TIFR approved the expenses.

All my expenses up to the US were paid by NASA. NASA had invited me to give the talk, and TIFR said I could go around the world. So I went to see Martin Ryle and asked him what he thought about the proposal.

Now there was a definitive direction. It was not about building the Kalyan Telescope and thinking about something tomorrow. It was very clear that nowhere in the world something like this was even being contemplated – 500 meter long, 30 meter wide parabolic cylinder built on a hill slope.

IC: And there were just the three of you?

GS: I was alone.

IC: You were alone at that time.

GS: I was alone. Kundu and Kochu Menon didn't even know about it. I was sitting in India and I may not have written to them straight away. I may have written later saying I had this idea but I don't recall very well.

IC: But you didn't need more people?

GS: Yes. It became a challenge to get Sharma and Joshi to TIFR. Oort wrote well of Sharma. Dennis either wrote or spoke highly of Joshi when I met him in Paris. Joshi was offered a job after his Ph.D. to go to the US. And he was another stupid fellow (!) and decided to return to India after France. If he was alive he would have been very delighted to meet you. Since my return to India he was my best friend. We had a lot of drinking together, lot

of solving problems, all together. Sharma had a different style, he is in Hyderabad. If you have time you can interview him. He had a very interesting way of looking at things.

By the way, have you seen the letters from Prof. Radhakrishnan, the son of C.V. Raman?

IC: Yes.

GS: Okay. I mean he is not in TIFR and at RRI and very supportive. So I tried to convince Sharma and Joshi to join us. They joined somewhere in 1964. Martin Ryle said, 'Build it in the next three years.' Now there was a man called V. Krishnan in charge of the workshop at Trombay, who had built lot of things. He set me behind by one year because he wanted to grab the design himself. He kept saying he was finding engineers, structure designers.

A year later, Dr. MR Srinivasan (who became Chairman of DAE much later) told me to get a Consulting engineer firm. But Martin Ryle had told me not to get consulting engineers because they make the radio telescope look like bridges! The Jodrell Bank Telescope actually looks not very unlike like a bridge! If you read the story of Jodrell Bank telescope – it's huge with a frame made of welded steel, a totally large design for that era.

The mega projects done through history of technology are absolutely amazing. What is GMRT compared to these? Nothing.

IC: But tell me a little more about life in TIFR at that point.

GS: There were two aspects. The new Kenilworth building was perhaps one of the few tallest buildings in Bombay. It was 10 stories high. Bhabha had purchased the land that belonged to his aunt for atomic energy offices. Four flats were allotted to three radio astronomers - Kochu Menon, Kundu and I. And the fourth was to Siddiqi. Then Kochu Menon and Kundu did not return. So the flats went to Devendra Lal and Daniel instead. The other day I was making a statement to Siddiqi to which he did not fully agree. I said among the four people allotted those flats, three of us became Fellows of the Royal Society. Was this Bhabha's judgment for potential leaders or was it that because he had allotted us the flats in contrast to lot of other people in TIFR, we felt a greater responsibility?

IC: So in TIFR at that point who else was there in your group?

GS: To begin with there was only myself. Then we hired Kapahi and Isloor in August.

IC: What were they hired as?

GS: Research Associates. They came from the BARC training school. Kapahi had high grades so he could choose what he wanted. Isloor wanted to do radio astronomy from TIFR but he was just below the 60% cut off. But Menon said, 'Take him, he is very dynamic and you'll need people like that.' But I was a bit hesitant.

IC: So you had these two and yourself?

GS: Yes. And then soon after that we hired two technical assistant - Pandit and Shinde. They started to put together that equipment that we had from abroad. I recall that in the first year there were only five of us – Kapahi,

Isloor, Pandit and Shinde. There was one more person whose leg got cut off by a road roller. We made him in charge of the Kalyan Radio Telescope.

Now when I came back from abroad, I decided to push for Ooty. The dishes had already arrived at TIFR. But Menon said I should push for Kalyan Radio Telescope because that would enable me to set up a group. Joshi and Sharma had not joined yet. I also told them not to come until TIFR had given accommodation. So I don't think they joined till mid-1964.

IC: So in the meanwhile you started work on Kalyan?

GS: Yes Menon said get going. In fact I remember one day I saw Bhabha getting into the lift. Normally people avoided taking the same lift as Bhabha. (This was after your NASA trip?) Yes. Anyway, I rushed up and joined him. I told him the project was well supported across the world. He asked, 'So what are you going to do?' I told him that Menon thought we should continue work on the 32 dish radio telescope. Kalyan had not yet been identified. We should build up on solar array first, simultaneously while making up a group. So he asked, 'Are you sure? Do you think you will be wasting your time?' Something to that extent. I told this to Menon later who said he would speak to Bhabha about it. Then as it turned out he approved the Kalyan Telescope. While writing the history of TIFR you must somehow bring Dadabhai in through someone's interview. He treated TIFR as his ship, cleaning, in charge of the administration services.

IC: Who was Dadabhai?

GS: Isloor will remember the name. He was in charge of transport, cleaning everything. He was a retired Navy man. So he advised us to go to Borivili

and other places in order to look for a suitable site. Then there was Prof. Gokhale, who has unfortunately passed away, otherwise you could have interviewed him. He was a cosmic rays pioneer and he said there is abandoned airport strip near Kalyan. So we went there. Kalyan could easily be reached from Bombay by train. So it was easy and practical. If we were not talking about Ooty, we would have looked for a better site which would last for longer time, where we could build larger array. But here speed was important. Later by September, October or November we started designing. Ooty was not yet selected so this had to be a bit fast.

We wrote a paper later in 1970 on how to make a detailed map of the sun using a low-cost telescope. In 1963 I innovated a transmission line which runs 2000 feet long and requires no amplifiers. And we could put this up in a fast way. That was the secret of Kalyan Telescope. Otherwise Kalyan couldn't have been built so fast. It was described briefly in our *Nature* paper.

IC: Did you fabricate it in the workshop?

GS: The dishes and mounts were there but supports etc. had to be made. The TIFR workshop helped increasing the heights of the mounts, and so on.

IC: And the transmission lines?

GS: Transmission lines were erected by the Indian Cable Company. There was an Englishman settled in India, who said he would erect it when we advertised. He was quite a remarkable man and he put the transmission line through copper wires 9mm diameter, running parallel.

IC: Parallel to these two ball point pens?

GS: Yes. They were supported at the end with heavy weight so that it keeps taut and we connected to the focal point dipoles through directional couplers. And by April or May ’65 the telescope was working. I don’t know how.

IC: And you began getting your data?

GS: Yes. Our first paper was sent to publications in ’65 or early ’66.

IC: It got accepted quite quickly.

GS: I’ve not seen the dates.

IC: Yes it is quite good.

GS: There was a story in the *Times of India* center page about it – India’s first radio telescope. A person called Sharma, who is the *TOI* man in London now, came to interview me. He was a young man then.

So now the question was where to look for a site.

IC: For your larger occultation telescope?

GS: Yes. We had advertised for structural mechanical engineers in ’63. And there were only 11 applications. Today if we advertise even for a cleaner there will be 2000. I saw in yesterday’s newspaper that for 22 posts of policemen, there were 27000 or so applicants. That’s unemployment today. We got only 11 applicants also because the IITs had not yet come up or were just coming up. So many engineering colleges were not there.

And so it became clear from whatever work we were doing that you cannot build next the cylindrical telescope in the Western Ghats because the slope

would be too large. It would be more economical to build it nearer the tip of India. The Survey of India maps were classified then.

IC: Okay, so you could not have them easily.

GS: Yes it was very difficult. Our friend Gokhale had some because he had been involved in balloon flying. So I could figure out from these, where the slopes existed and where they didn't. So I told Dr. Bhabha that I wanted it in South India – either Ooty, Kodaikanal, Salem or Mysore. I thought it would be nice if it was near Mysore because it was near Bangalore. So Bhabha asked me to accompany him to Delhi and introduced me to a person in charge of the Survey of India maps. Bhabha had written a letter and he was already a larger than life figure. So all the required maps were made available to me. The only thing was that I could not take them out. Anyway, I selected 60 potential maps. I went to Bhabha and got 60 copies. They are probably somewhere in the TIFR library, supposed to be kept as secret.

IC: But Ooty was not a natural choice?

GS: No. So in January '65, Kalyan was not finished but it was on the way. Isloor and Kapahi were busy with Kalyan Telescope and I needed somebody else. I had learnt in my geography how to make an inclination from parallel lines. So in January '65 I did that. I requested the great photographer Upadhyay; I made drawings, drawing sections, parallel lines. He photographed two 11 degrees, 10 degrees, 11 ½ degrees, 9 degrees, 9 ½ degrees on glass plates.

IC: Okay. So, it was some work you did there, working out how to find a potential place.

GS: Then Ramesh Sinha joined from the training school in 1964. Kapahi, Isloor, Sinha, Sharma and Joshi were the only scientists. All the others were technical assistants. Bagri joined in ’64 from BITS Pilani.

In January ’65 I flew to Bangalore. So Ramesh Sinha and I went to Bangalore. Ramesh Sinha went in a jeep with the driver Joseph. And we went to Chamundi Hills in Mysore. We didn’t know anything about it. All that we knew was from the Survey of India maps. When I saw Chamundi Hills I said, ‘no way’. There was too much of population, just next to the city. And we continued towards Ooty.

So we went to Ooty in January and selected three sites. One site was beautiful but full of coffee estates. We knew it would be difficult to acquire that. Another one was near a lake. I had learnt from Menon and others that Bhabha had been to Ooty earlier, he was trying to search for a place for inter-university centre. Bhabha used to go to Ooty often for vacations. One of our sites happened to be quite near the potential site of the inter-university centre. It was different because our site had to be on a slope and accessable. The third one was in a reserve forest, some 6-7 km south of where we are now.

While we were surveying the first site, a local Toda guy appeared. He was very curious about what we were doing. He took us to his hut across and we talked to him. Joseph, the driver, was our interpreter and he was told not to tell what we were up to. The Toda guy offered us a glass of milk, fresh from his buffalo. I had just returned from the US and was not ready to drink milk straight from a buffalo, however fresh. So I told Ramesh to drink it up. (Laughter) And he still recalls that.

It was a good site, overlooking a lake, though a bit far away from the town. Looking back I think this would have been a better site and there would have been less interference. But then the site we have at present was closer to town and we could go in the evening, morning so on. People could stay in town.

IC: And the slope was right?

GS: The slope was right. At the earlier site we would have had to do a bit more earth work.

And then we continued to Madurai, because Professor Bernard Peters said we should put optical astronomy, done by Vainu Bappu, and radio together. He suggested Kodaikanal. I went to Madurai because I had some potential place close to Madurai town. It is quite a story about how I ate on a banana leaf without spoons for the first time and so on. Kodaikanal was a potential site but would have cost a lot more. Then Salem was another potential site near the city. We were just surveying, the decision would be taken later.

And as we were going from Madurai to Salem, we passed through a town called Namakkul. As we came just outside the town we realized the anti-Hindi riots were going on. This was 1965. People suggested we took the bypass. I had the Survey of India maps and we could bypass the road because the great Ramesh Sinha wanted to attend the marriage of his son. Our jeep almost got burnt before we reached Salem station. Many came with *mashals* and we had a theodelite in the back; Joseph put the back cover of the jeep fast and asked us to shout some words in Tamil: down, down, Hindi and up, up Tamil! That saved us.. Then we dropped Ramesh Sinha at the Salem station.

I went to Kolar and visited the Cosmic Ray laboratory of TIFR, deep in the mine and was very impressed. Then I went to Bangalore and flew back. I made a comparison of the Kodaikanal vs Ooty. I had made the report describing library, workshop, approachability, etc. Bhabha wrote on the margin – library can be built, workshop not important, and approach very important. He said it looked like a Wimbledon match, the way I had compared the two sites.

IC: And Ooty won.

GS: Yes Ooty won. Now this was February-March 1965, Bhabha decided to visit this site in May. There were two sites in Ooty and he said he must go and select. I think he went twice, first in May and then again in December with me. I got unwell in May with an appendix problem, so Sinha accompanied him.

Venkataraman was the Minister for Industries and Bhakthavatsalam was the Chief Minister. They made Bhabha a state guest during his visit to Ooty and the PWD chief engineer came and went to the site to help him. Bhabha made everyone run after him down the slopes. The chief engineer was not such a healthy man and had a paunch. And Bhabha was running and saying let's see if this man falls. Everyone thought Bhabha was a serious man but he was also child-like.

IC: He didn't actually make them run!

GS: He did make him run. He went fast and they were trying to keep pace with him. Bhabha had a sense of humor. He was child-like in the sense of

dealing with people. I don't really know what I really mean, but that's my impression.

IC: So then Bhabha liked this site better?

GS: No, the selection was not done then. He went with me later. He must have figured Ramesh Sinha out. He talked too fast. We can have a whole tape on Ramesh Sinha.

IC: Where is he now?

GS: He is in Washington D.C. Poor fellow has Parkinson's disease. He is suffering.

I had selected the site but Bhabha was not finalizing. Then he asked me to come to Bangalore – he took a vacation every year to Bangalore. And TIFR said I could fly there and stay at the West End Hotel. We went over the details. Bhabha said I should meet M.R. Srinivasan the BARC Chief Engineer. M.R. Srinivasan had recommended to hire a consulting engineer firm but as I told you before Martin Ryle had said not to have consulting engineers. I was talking to a variety of people for the design. Perhaps by mid-65 I did go to Bologna and got a few drawings as well. So, I knew precisely what had to be built.

IC: So when did the site get finalized?

GS: In August Bhabha approved the hiring of Tata consulting engineers. We had done that much of work earlier, comparing, and advertising. Dastoor and Co. were very keen. 17 people had replied to the advertisement for the

designing of the telescope, including the great engineering firm Krupps from Germany. And the Krupps were like the Tatas of India.

Husband and Co. who designed the Jodrell Bank telescope also replied. Hoover from Larsen and Toubro was very disappointed that we didn't choose them, instead of the Tatas. He wrote a letter in protest. I replied that we wanted someone in India to design it but Larsen & Toubro wanted to consult their associates in Denmark. He replied saying Larsen and Toubro were in India. Perhaps, it should have gone to Larsen and Toubro. They would have been more professional. Ooty would have come faster with Larsen and Toubro. However, they made a mistake of getting a drawing made in Denmark as part of the tender.

IC: Larsen and Toubro?

GS: Yes.

IC: And that wasn't approved?

GS: So it was clear to me that we'll design it in India. I had talked to Martin Ryle and also was aware what Australians had done. I had seen not only the 50s but also the great projects Indians were doing in the 60s . And I already told you, from my background I could already see that it was not difficult to get man power in India and make them work.

IC: So at what point did it get approved?

GS: He approved Tata Consultancy at that point. And in December or late November he decided to make a visit to Ooty and Madras. Now it came in the newspapers that one of the potential sites was also part of the Toda

reserve forest. The issue was also raised in Parliament. And then around 700 Todas came during our visit. They performed their traditional dances and it's very unfortunate that I didn't have my camera. There was a Toda woman, who at the age of 12 or 14 was married to a German. She was later divorced and got her education from England. She organized the whole thing. There were dances and then tea. I was never into dancing but Bhabha played to the hilt.

IC: In what way?

GS: He was meeting them, talking to them, and welcoming them.

IC: So there was a massive Toda representation.

GS: Yes massive.

IC: But they didn't want it there?

GS: Yes. But Bhabha didn't tell them our plans. Now he wanted a 600 acre non-agriculture site for the inter-university centre. So from the Survey of India map – I had mastered them by then – we located a 600 acre site between the Golf Course and the Ooty Telescope.

In December he approved the site. In fact the cosmic ray building was also much smaller then. But Bhabha told me that land was available so we should acquire it. In due course we might need more space. So that was his foresight.

And then he asked me to come along to Madras to meet Bhakthavatsalu. I don't recall if he was still the Chief Minister but I certainly remember going to Raj Bhavan. I also have distinct and very clear memory of meeting

Venkataraman, who became President of India later. Bhabha took me to Kalpakkam also and said he was considering sites in Tamil Nadu, Karnataka and Maharashtra. He didn't reveal his mind.

Ooty site was a reserved forest but Venkataraman said the main part need not be totally given to Atomic Energy. It can remain a reserve forest but given on lease to Atomic Energy for 25 years. So in December the Ooty Telescope was approved. Both the consulting engineers and the land were approved.

Then during the Bangalore meeting at the West End hotel, Bhabha told me he would give Rs 50 lakh for the radio telescope from Rs. 2 crores he had got from Nehru for the inter-university centre. I didn't know about the inter-university centre before this. Originally I had projected 35 lakh but Prof. Phadke looked at my budget and said we should make it Rs 50 lakh. I wish I had made it Rs 60 lakh. That would have made things much more comfortable.

Then Bhabha died and getting each penny became difficult. The successors didn't have a vision. Sarabhai was there but he was treating things in a very different way. I feel if we build something the aim should be for it to last. Scientists should not suffer because something was built trying to make do with very limited money.

Then the Indo-Pakistan war took place and Bhabha announced that India can make the bomb in 30 months. He made a big mistake of telling this to the media. Morarji Desai, who was the Chief Minister of Maharashtra then, was very opposed to this.

By this time I had been promoted to the position of Associate Professor. I told J.C Jain that I was going to have lunch with Bhabha at the Faculty Lounge. He said ask him about the critical problem in making a bomb. Remember I wrote an article in Christian College on atomic bomb?

IC: Yes, you told me.

GS: The McCarthy era had started in Stanford and I didn't tell you that they hounded Christianson, one of my mentors. When he came to IAU in 1961, he was not allowed to land in USA. Because his brother-in-law, his wife's sister's husband, was considered a fellow traveler of Petrov the first secretary of USSR, who had defected in '53 or '54 from the USSR to Australia. So in the process they were investigating all fellow travellers to Australia. Christianson was not directly involved. Chris went to China in 1961 or 1962 to build the first radio telescope there. Later Chris came to India to visit us at TIFR. He heard all about the Ooty plans and said, 'Govind don't you think you should build a Synthesis Telescope?'

IC: And which year was this?

GS: 1963 or early '64. And I thought seriously about it. There was no way we could make large dishes then. We didn't have the technology. No doubt, it was a good way of doing it. But I could see that I couldn't do it. The Ooty Telescope was easier to build.

Bhabha walked in with a glass of juice and I asked him what made him think in '44 that nuclear energy would be possible? So he looked up and said, 'Oh, because they were not publishing.' I have quoted this line to many people.

IC: So it was clear that something was going on.

GS: Yes the question was what else they could have been doing. People who had been publishing regularly had suddenly stopped. What project could they be working on?

So a bit later I asked him what the critical problem was in making a bomb. He said, 'You are from Stanford. You've done a control engineering course. I want to talk to you after I get back from Geneva.' He could see that I could play a very important role with Seshadri, who was one of the 10 persons who made the bomb. Although as an astronomer, I didn't believe in atomic bombs. Most unfortunately, Bhabha did not return from Geneva as the Air India plane crashed in the Alps Mountains.

We then went ahead to build the Ooty telescope. Tata Consulting engineers were approved, Sharma and Joshi had joined, and site had been found. He also did a very important thing by the end of '65, before he died. Kalpakkam was there, so he asked Bhakthavatsalu to see the confidential file of PWD for reports on the young engineers who would be eligible for promotion in a few years. He was looking for dynamic engineers. Ramaraju, who later became an important man in TIFR, was one of them. Dharmalingam, whom I should call Adharmalingam, was the second one who was assigned to work for our team. And also Rashid Ahmed, who became our Project Manager later. Earlier Dharmalingam was allotted for Ooty Telescope as a Project Manager. And the money was allotted. Then because Bhabha died, Venkataraman wrote the letter to the Collector, requesting for a little extra private land without which the slope couldn't be used. Earlier, for finding a slope I made Ramesh Sinha walk up a slope and looked at his nose, leg and feet and checked the slope by R Theta = height. I used that.

GS: So in April ’66 I went down to talk to the Collector – Ahluwalia if I remember the name.

IC: This is already 66.

GS: Yes. We wanted to start the earthwork before the monsoons. I remember Ahluwalia asking me, ‘Prof. Swarup what is the life of a star?’ I said, ‘Millions of years.’ He said, ‘Then why are you in hurry?’

IC: What a question!

GS: Then I described the situation to him and he of course helped. One of the important questions that arose then was how to get water to this place.

Then in 1966 the Tata Consultancy engineers started making the drawings. Once the drawings had been done, 2 million cubic feet of earth work had to be removed. Someone suggested automation but Rashid Ahmed said we should give the contract to a contractor of the Tamil Nadu Electricity Board.

IC: Why did he say that?

GS: Well, they would have contractors. Instead of automating, this was a better idea.

IC: Okay, so you used man power.

GS: Yes manpower. In 1967 I went around the world again. I showed people the photograph and said it was the world’s largest radio telescope and 500 people were working on it!. It was the world’s largest radio astronomy group. I flashed the photograph where a large number of men and women were doing earth work.

IC: Do you still have those photographs?

GS: Yes, but Isloor must come and help me. I don't have time to do all this. If not Isloor somebody else should help me. My wife refuses to see those colour slides for some reason.

IC: We need those. I will tell Isloor if he is planning to come.

GS: It will require a day or two.

IC: Then we can digitize and use them later.

GS: Yes. I have all kinds of photographs.

IC: Okay, so the earth work began in 1966?

GS: Yes in '66-'67 we had placed the contract okay. I recall I went to Calcutta on my way to Australia. I with Ranga Rao of Tata Consulting Engineers met the people of Bridge and Roof there and recommended to give the contract to them.

And Ranga Rao of Tata Consultancy was very bright. Ranga Rao became in charge of TCE later on. There were only 30 engineers in TCE at that time. Some came from Damodar Valley. Menon thought they were a young group of people who would do the work more enthusiastically. The project started getting costlier and we had problems getting more money sanctioned. The roads and buildings had to be completed before TIFR could transfer Sharma and Joshi and other scientists and engineers to OOty.

In the summer of 1968 Sarabhai planned to visit Ooty. Bhabha had died and Sarabhai became Chairman of DAE.

So Sarabhai wrote a letter to me expressing his wish to spend a week with his wife there. He wrote rather late and all places had been booked. One PWD chief mentioned this to the Governor Sardar Ujjwal Singh. Ujjwal Singh said, 'Let him be my guest.' Vikram Sarabhai was in Trivandrum. So I found out his phone number, phoned him and said Ujjwal Singh had invited him. He didn't like it. He said, 'Govind, can't you do something else?' There was one condition by which he had to take lunch with Ujjwal Singh everyday. Other than that he was free to do whatever he likes. Sarabhai didn't like it. I talked to Mrinalini who said, 'Govind go ahead and fix it. Don't talk to Vikram.'

IC: The Raj Bhavan is a beautiful place.

GS: You have not been to the main building. Have you?

IC: Not inside.

GS: You must go inside. I have not been there for a long time. I hope they have maintained it. Anyway, so that's where the Sarabhais stayed. They had this young 18-year-old girl whose name is Mallika.

IC: Oh Mallika!

GS: Yes. So they came and the first frame of Ooty Telescope was being taken up through pulleys. And Vikram Sarabhai asked me, 'Have you seen Zorba the Greek?' I had not seen it. He said I must see it.

Vikram had a great sense of humour. He would laugh and tell me, 'Mallika always says you are like Prof. Calculus.'

The other day one of my neighbours told me that her daughter also calls me Prof. Calculus. Thirty years later I am still called Prof. Calculus.

Anyway, the Ooty Telescope was constructed but we had made a bit of mistake.

IC: When was it completed?

GS: It started rotating in 1969 December. The first observations were made on 18th February 1970. The first occultation recorded was published but here is the photocopy of the original chart. I remember once we didn't sleep for 36 hours. Occultation of one radio source was predicted at 4 am, but before that something else occulted at 10-11 pm. So we continued to wait and watch chart recorders output.

In mid 1965, the Indo-Pak War happened and there was meager foreign exchange available to TIFR. Sarabhai approved available foreign exchange to DAE and space. Whatever foreign exchange came to TIFR very little came to our group. So somebody suggested why don't we apply to the National Science Foundation? We applied for $70,000.

Later, I went to the United States in 1967. I was looking for a computer and $40,000 was the lowest possible price. So out of $70,000, 40,000 disappeared.

Looking back the grant from National Science Foundation seems like an extraordinary achievement. The radio astronomers in the US also recommended us, calling our project a world-class one.

Anyway, we got developed low loss coaxial cables by a firm in Bombay; for the required specification, we used World War II microwave books. We also got made the coaxial connectors but were worried about how to get made large gears. There was a young 30-year-old engineer, named D. P. Panchaal from Tata Consultancy Engineers, who was designing the mechanical drive system for the Ooty radio telescope. At first TCE recommended a more senior person but his expertise was putting machineries together. I wanted somebody who would do detailed calculations with the expertise of a bright student. In those days very few people did systematic calculations. Design was not passed on to young people. Senior people imported and put it together.

Procuring large radius gears for the Ooty Radio Telesope was a challenge s no firms made them in India. A ship was docked in Bombay and Panchaal said it used large steel gears using pin wheels, like the ones I had seen in my young days in wooden rotating devices driven by bullocks. We went and saw that, so it became low cost pin sectors of the Ooty Telescope. We used round rods of ~ 30 or 35 mm diameter as pins placed periodically in a fabricated channel to form the large gear. We later used the also pins for GMRT, something that we should not have done. We should have used traditional gears even though costly. So we made our own gear drives. That delayed the process.

IC: So you made those gears in TIFR workshops?

GS: No. But the design was done by Tata Consulting Engineers. Panchaal used the basic engineering principles. Another thing that delayed us was the process of balancing it. Ranga Rao asked why we needed to balance it

because the Bologna telescope was not balanced. Ranga Rao said the telescope was designed for maximum wind that has much larger torque than that of the unbalance load. One can carry 20-40 kg loads but if a kg is fixed to your shoulder permanently you would not like it. That's the principle we learnt after the accident. We must balance it for long life. So all subsequent telescopes built in India have been balanced.

IC: But this one was not at that time?

GS: Originally it was not balanced. But later on an accident took place. Ranga Rao thought we could never balance it as its original design would not allow it. Then a very senior Russian engineer visited Ooty, who checked and agreed with my idea. He didn't understand a word of English conversation but he checked all calculations based on equations made by Shri Ranga Rao and colleagues, pre computer days!

IC: So which year did the Russian come in?

GS: He came in '73 or '74. This was well after we had fixed the radio telescope because the accident took place in '71. The day India entered Dhaka.

IC: Oh, same day?

GS: On the same day. Kapahi and I were listening to the radio. Then the accident happened and at night it looked like all the frames would fall on each other like a pack of cards. Later I bought a book on mechanical engineering from Fountain at Bombay for Re 1. I must show you that book.

IC: Yes. And then you started repairing it. My goodness this is amazing. You have kept it this long. We are going to photograph this book. Some of the pages with your comments on it. It will make a good display of what you were teaching yourself at that point.

GS: Every calculation of mechanical design of the Tata Consulting engineers was cross checked. But we learnt from basic physics, how you can check the basic calculations. After all this is taught in BE first year, so why can't a M. Sc. Physicist do that?

IC: So, that's what you used?

GS: Yes it should be trivial for M. Sc. Physicist.

IC: This book is called Applied Mechanics for Engineers, bought by Govind Swarup in 1965 well before the accident. This is J. Duncan's book.

GS: This book is from the 1930s or so but it tells the physics better than the later ones. It says September but I don't see a date.

IC: We are looking for the date for this book by Duncan. It doesn't seem to be printed here.

Session Six **Date: 29th April 2006**

IC: Prof. Swarup, last time we had talked about the Ooty radio telescope and the way in which you went about building it. Today I want to pursue another line about the Ooty radio telescope. Basically I want you to tell me a bit about the major work that came from that instrument and then may be we

can talk about collaborations. Then finally we can come to GMRT and how that very large programme was conceived.

GS: In 1965 the Indo-Pakistan War took place. Then in ’66 January Bhabha died. Getting foreign exchange became very difficult in TIFR. So we made a proposal to the National Science Foundation. We got the grant.

Bernie Burke asked me at MIT how I planned to record the data. I said with chart recorders. He suggested using computers but I thought they would be too expensive. A mini computer had just been developed in the US and he said we should consider that. It cost about $40,000. So out of the $70,000 from NSF, $40,000 went away to the computer. So we were left with $30,000.
It was a good computer but we didn’t get the digital and analog converter because we thought we would build it ourselves. But we couldn’t manage to build it. So all the data was recorded by chart recorders. Everything from chart recorders was transferred to those punch cards. We gave the lunar occultation observations in ’70-’71. We continued with the observations till ’75-’76 after the telescope was fixed in ’73.

I requested an electronic technician, Manohar Modgekar to meet me, who became a very senior person later. He was a very hard working fellow. One evening I requested his help, because I wanted the results faster. I requested him to classify radio sources into different intensity bins after finding out their angular sizes from the catalogue which we had prepared already. Next morning when I came there was a relation – the weaker Ooty radio sources were much smaller than the well-known stronger radio sources of the 3C

catalogue. Kapahi was simultaneously doing angular size count and he wrote to me saying he was giving a colloquium. Now he is not there anymore so it would not be really correct to recollect the incident. But for a while I thought let him write the paper and then I will publish the relation. Then I thought he was my student and couldn't do this. So Kapahi described these angular size counts as well the above result in a colloquium.

IC: In Bombay?

GS: Yes in Bombay. In TIFR, in the famous physics lecture hall. I told him he could put the angular size-flux density and angular size counts together. He asked me whether we should share the papers. I said this was the first major work of our group and people will refer to it as Swarup's paper, so I will publish my angular size results and you publish its interpretation. The papers became extremely famous because it showed internationally that not only the weaker are likely to be far away, hence their angular size should be smaller. This was the concept that led me to propose the Ooty Telescope in '63. Then whatever purpose for which we built the Ooty Telescope got validated and it was presented in an international meeting. I remember in '67 Harry van der Laan, who became the Director of European Space Observatory, came and asked me whether I was sure about the results and their interpretations. I didn't tell him and others that we had digitized all the chart records manually at Ooty every mm and then analyzed them in the CDC 3600 computer at Bombay. They wouldn't have trusted us. I didn't reveal to them, but we had done it carefully. We had hired some very hard working young people for the work.

Now simultaneously, we had formed three-four groups while the Ooty Telescope was being built. There was the interplanetary scintillation group comprising Pramesh Rao, Ramesh Sinha and Ananth Krishnan. The occultation group had Joshi, Kapahi, Gopal and C.R. Subramanian. In the second occultation group, Kulkarni was working with Kochu Menon using international data. There were a few other people in this group. The other group was the pulsar group. The pulsar and interplanetary scintillation were well defined groups, and all the members of the group did outstanding work and became world famous. In the occultation group, whether radio galaxies, quasars, or galactic centre got occulted, depended upon where the dear *chanda-mama* (Moon) was. What part of the sky the *chanda-mama* appeared to reveal the secrets of the universe behind him. I may also refer to a paper with Gopal Krishna which was published in *Nature* and its results quoted in a Symposium in Australia saying that Gopal Krishna and Swarup had shown for the first time the true nature of the Galactic centre. There was great controversy about its nature till about ’67 or so. C.R. Subramaniam did most of the data analysis of the occultation records. Large number of papers was published based on Ooty occultation observations, IPS, Pulsars etc., including 6 papers in the Nature during the first 7 years of operation of ORT. Our occultation work showed that there was evolution of the Universe. Already in 1965 microwave background radiation had been discovered but a lot of people, including Narlikar, had lot of criticism about it. They pointed out that it could not be due to early universe and could be because of something else happening in the universe. But now we had very clear evidence that radio galaxies showed cosmic evolution. In 1979, after 16 years in TIFR, for the first time I decided to take a sabbatical. I was allowed

a sabbatical every six years but I was busy at Ooty. While on sabbatical I met lots of people.

In 1975 we sent Kapahi's thesis to Martin Rees, who is now the President of the Royal Society. Rees was a famous young man then. I had asked Kapahi whether to send the thesis to the best expert and he said yes. Please look if Kapahi's confidential file is available. Rees replied saying he had read many thesis but this was exemplary, not only science wise but English wise. That's why the letter would be good to see. This was probably the first thesis that went abroad around that time.

The years that I was abroad are very interesting but I will cut it short. In 1981 Pope requested Father McCarthy, who was in charge of the Vatican Observatory a Conference. The Pope said one should not ask who created the universe but evolution of the universe can be studied. Anyway, the conference was organized and 25 people were called. I was one of the 25 people of which 3-4 were Nobel Prize winners. Stephen Hawking was sitting on my right hand side and Weinberg was on the left. Unfortunately I don't have a photograph of that.

IC: I suppose we could write to the Vatican.

GS: A journalist from England has been trying. But I haven't had the time to reply to his mails. He is very interested in the character named Govind Swarup, 'who sails from Mars'. He is extremely impressed by whatever we have achieved.

IC: So this was the Vatican conference of ’81?

GS: In which Indian work was presented.

IC: And at that time you were in Leiden?

GS: No. I had returned to India then and had gone back later. Earlier, when I was at Leiden, my distinguished professorship appointment was signed by the Queen of Netherlands. Unfortunately I don’t have a copy of that. But it might be available in the University of Leiden Archives. There must be a file somewhere. I am going to Leiden in June.

IC: Yes we can write from the Archives.

GS: You send me an email I will forward to the person concerned as well as the Director of Leiden Observatory as well as Harry van der Laan who invited me.

Coming back, that was recognition for the Ooty work. That is a very important point.

IC: Can I ask you one question about Kapahi? How did he become your student? He was from the training school.

GS: In 1963 I had just returned from abroad and gave a talk at the DAE training school. Professor Menon asked me to do it. The idea of the Ooty Telescope had occurred so I went and gave a talk about that. So on 1st of

August Kapahi and Isloor both opted to join the Radio Astronomy group. Already Bhabha had formed the group with four of us and it was a new major thing in the institute. With Kapahi and Isloor we built the Kalyan Radio telescope. Kapahi had the leadership potential and after his PhD thesis he was offered a post doctoral position at RADASTRON near Groningen. He did very important work there, after which he returned to India and continued the good work in a variety of topics. When he died he was still very interested in cosmological evolution of radio galaxies and quasars. He became an expert in the field of radio galaxies and quasars. Saikia became Kapahi's student and also Prijaval. They also worked with me but they were guided essentially by Kapahi.

IC: One more question that struck me when you talked about your analysis of data and you know how you digitized it. When you were buying this computer on which you spent so much of your money, did you consult the computer group in TIFR?

GS: Well, the computer group in TIFR must have been consulted for sure. But Sheshagiri, who was at the department of electronics under Prof. Menon, was the chairman of a Dept controlled what computers should be purchased. Because it was the first mini computer being purchased in India, they thought we should strike a deal so that they would offer the lowest possible price. There were only two mini-computers available at that time – PDP and Varian – and so the question of negotiation did not arise. IBM was much more costly. Unfortunately, we didn't have an analog-digital converter. We should have thought about it then. But it was difficult because Sarabhai was not so supportive, every foreign exchange available he kept for

DAE and ISRO. Now he is no more. If he was there I would have had a discussion with him and ask him as to why he didn't support us more. We were already well-known in the world but we would have gone much higher if he had supported the Inter-university Centre at Ooty. Then in 1973 or '74 we were suffering heavily because of the lack of a digital recording of data and pulsar work couldn't be done without that. We had to send records to Bombay - so we were transferring the data from Ooty to Bombay through tapes and not punch cards. We didn't have a punch card machine in Ooty. There is a story about this – this was sometime around 1973, Sarabhai was abroad. (Sarabhai died in 1971) When did Sarabhai die, in 1971? (Yes). But it just couldn't have been 1971, it had to be '72 if not '73.
I find it very surprising that nobody has yet written Sarabhai's biography.

IC: One biography is coming out from Penguin this year.

GS: A book?

IC: A book.

GS: Who is writing it?

IC: Amrita Shah

GS: Where is she?

IC: She is based in Bombay. She is a journalist but now wants to write only on focused subjects. She is also a consultant with Indian Express.

GS: So why not get her to write the entire story of radio astronomy?

IC: She comes to the Archives to do research.

GS: See the purpose will not be to highlight us. It would be to show India's contribution and what we have done.

IC: I will talk to her.

GS: So, now coming back, I have got lost.

IC: You were talking about 25th March 1972 or so and something about Sarabhai.

GS: Sarabhai was abroad and so Menon phoned and told me that there was some foreign exchange available and whether I needed it. So I flew from Ooty on March 29th or 30th and that foreign exchange got transferred to Ooty to buy an analog digital converter and a printer. These were the only two things we got. The people with power had such narrow vision. I really didn't understand why. I can't say Sarabhai didn't have vision. He was most distinguished and father of India's Space programme.

IC: And this is something that others have said in different ways and at some point of time it stops.

GS: Sarabhai had vision but somehow they don't look at things nationally. They start thinking only about their priorities. There is one such person in the country today. I wouldn't like to name him. They have their own ideas about what should be done or not done and sometimes they might say okay to your ideas saying it would take place in due course. Of course there are also people like Bhabha who are internationally aware of the importance of what is happening, they know how to look at the field as a whole. Sarabhai was chairman of the Atomic Energy Commission. While his biography was being written I would have liked to put in some of my views because all praise is not a book. It should be both positive and negative.

I will tell you one story. In 1965 Bhabha had planned an inter university centre. He told me that he would make the Ooty Telescope a part of the inter-university centre. I said I had to build a telescope and take it to an international level. But he said in due course I would need manpower. I agreed. The inter-university centre was to have teaching and research and that made a lot of sense. Prof. Rai Chowdhury, who is a distinguished physicist from Calcutta and now a director of the Harish Chandra Institute, gave a talk the other day saying 500 crores is very easily available today. Any money which goes to pure research is total waste unless it goes to education.

Coming back a great vision of Sarabhai. Sarabhai phoned me on 31st December 1968 around 10 pm or so and said, 'Govind, Indira Gandhi had asked for three test cases. Things that are being imported, can they be done in India?' He was in the Science advisory committee meeting in late Dec 1968. You could possibly get records of that – this was a historically

important meeting. Sarabhai told me that the Chairman of the Committee suggested they could write to various departments of the Government. Sarabhai said 'We were all part of that and if we did not know that such a case exists then it didn't exist! So this was Vikram Sarabhai, very vocal. He had this wonderful smile. So Sarabhai told me that India had decided to import a 30-meter dish for satellite communication. Till that time all radio communication to India and Far East from England, Europe etc was from some place near Pune through HF radio waves. India decided to build a satellite earth station. I am talking about 31st December '68. He told me we would have a meeting at 9 am in the morning. He must have understood something from my response because he asked me why. I said, 'Do you hear music in the background – the New Year's party is going on.' He asked till what time would the party go on. I said the party would generally go on till 4 am. We were in the US for seven years so we had the western mindset and we were all quite young then.

IC: Was this in Ooty?

GS: This was in Kenilworth in Bombay. So he said the party should go on till 3 am and we should meet at 10 am. Just look at Sarabhai. Of course then our party ended at 1am and I had a good sleep and met him at 10 am. I told him it should be possible to make it in India. Sarabhai asked to examine its feasibility. We wrote a proposal. Along with a few senior engineers of the Tata Consulting Engineers, S.S. Bhave of TIFR , Shah from ISRO from Ahmadabad and I went around for 10 days – to Richardson & Cruddas, Larsen and Toubro, New Standard Engineers etc. – and submitted a report saying that it could be done in India, within 18 months to 2 years. Then the

Arvi antenna was built. Tata Consulting engineers helped us. The drawings were totally independently analyzed by Yogi who was an M Tech student at IIT Powai and C.K. Ramesh and the results were checked with the imported things. I knew we could build any large antennas in India. Anyway, then Arvi got built and the rest is history.

IC: But what was the context of this antenna?

GS: For satellite communication of voice and data, it was the most important thing. Before that one relied only on shortwave radio communication with multiple hopes of less than 5 or 6 thousand km distances.

IC: What I am asking is was this for the first Pakistan War?

GS: No. It was part of the growth of science and technology. This was for communication across the world - whether you wanted to sell, buy or to phone your friends, you wanted to go abroad, anything.

In 1970, JRD Tata inaugurated Ooty Telescope and then some months later one Mr Agarwal, one of the nine members of Tata and Sons came. He came to me and said JRD wanted to start a Tata antenna and Microwave Corporation and wanted me to be in charge but I declined.

IC: When did you complete Arvi?

GS: Around ’68-’69 I was heavily involved with building the Ooty Telescope. Arvi was completed around ’71 and Indira Gandhi inaugurated it. He invited me but I was in Ooty and didn’t come. I was too busy doing work at Ooty.

Now let me talk a little about pulsar. I wanted Pramesh Rao to join the pulsar group. Only Ramesh and Anant were supposed to work for IPS. But Ramesh, who was a great organizer, roped in Pramesh because then his job would be less. But it was Pramesh and Anant who built the interplanetary scintillation. This was an extraordinary work.

So by end 1970 we had found a pulsar. It was published. Then we started a survey in 1971. Before the accident took place we had taken a lot of data. We made a bit of a mistake – we were looking in the galactic plane rather than outside that. You can ask D.K. Mohanty, who was part of the pulsar group and is in Bombay.

IC: You were telling me about the mistake that you were looking in the galactic plane.

GS: First thing, we didn’t have either a digital data recorder or a digital receiver. MIT had built a nice digital receiver. You need a digital recording data but you also require a digital receiver. I believe Jodrell Bank had done this and so I invited John Ponsonby to come to India. He came to TIFR for a year in 1971. I had met him at the Crab Nebula Symposium at Jodrell. I thought if he was interested to come to India it would be wonderful. He liked India and he still likes it. Then Mark Price had done some good work at MIT

and I thought it might be a good idea to collaborate. Anyway, Price came in ’71, but by that time the accident had taken place and so it didn’t go through. By ’73 after the telescope was fixed, we knew where we should go, what we should do. We had the recorders at Ooty but the pulsar search programme which Mohanty had built using 700 punch cards, did not work. He had put the cards but with no sequences. He had not put 1,2,3,4 and when they fell it was like ‘Humpty Dumpty sat on a wall… all the king’s men and king’s horses couldn’t put Humpty together again.’

IC: There were no sequences.

GS: Yes. It was a very innovative and clever programme.

IC: So that lot didn’t work?

GS: No that lot of cards did not work. So a fresh programme had to be worked out. At that time a very bright fellow named Krishna Mohan had already joined. He had been part of the Ooty-Parkes Radio telescope in Australia experiment. Before the accident of the telescope we had done simultaneous observation at Ooty and Parkes. Then the accident happened and the telescope came back only in ’73. I thought our main purpose was occultation; I had lost one and a half-two years. I concentrated my research work on radio galaxy and quasars s. Tanwar had just finished his PhD working on Cosmic Rays and Sreekantan recommended him for a Fellowship abroad. I told them to assign him to us for a year and then I would recommend him to the world. But he still wanted to do his cosmic research and went away. We couldn’t get anybody else from TIFR.

IC: For the occultation group?

GS: No for the pulsar. Of course Krishnamohan and Balasubrahmaniam did pulsar observations. Then Radhakrishnan joined in 1970. He came and saw the Ooty telescope and was very impressed. I discussed the construction of the Arvi antenna but he didn't believe it.

IC: So the occultation work went on with Kapahi?

GS: Kapahi, Joshi, Gopal-Krishna, C R Subrahamanya and a few others. By '76 we had come to near close in the Occultation programme. Now shall I come to GMRT today?

IC: I don't think because GMRT would be quite substantial.

GS: No I will try to cut it short.

IC: I actually wanted to ask you about GMRT through your collaborations.

GS: See the point is that a lot of work was being done by our group. There was Sharma, Joshi and Bagri. But I should come to that after talking about GERT. Ananthakrishnan also helped to design and build RF amplifiers for the Ooty receiver.

I haven't given you a copy of Davies (?), right?

IC: There is a letter?

GS: Yes quite a few.

Anyway, in 1970 or so, Sarabhai put me, a young man of 36 or so, as a member in a committee of Air Force authority who wanted to import some 50 crores worth of troposcatter antennas from Italy. There were 120 parabolic dishes pointed towards horizon from one to other in pairs – to be set up all the way from Assam to Pune. This was for the Air Defence Ground System (ADGES). TIFR also did important work regarding radar displays.

Soon after the China war, it was decided that India should have a troposcatter communication network, so that you could see instantaneous pictures from across the country of the data recorded by radars at a centre near Delhi. From Assam to Pune there would be an antenna every 30 miles. It was proposed that transmitters and antennas to have a range of 30-40 miles.

Sarabhai had approved indigenous construction of the Arvi antenna that was done within 30 months. We had shown to Defence authorities that computer programme for designing parabolic antennas in India existed and all the troposcatter antennas could be designed in India. We had also shown him the servo system that was done at BARC. There was a thorough demonstration of our capability. It was a story by itself.

IC: So Sarabhai knew that it could be done?

GS: Yes of course. He was the chairman. For both Bhabha and Sarabhai the attention to detail was very important. Though they dealt with it in their own different ways. For Bhabha and Sarabhai choice of people was important.

So, Sarabhai put me in the committee and the chief of Air staff division chairing that committee. Ooty was done, Arvi was almost done. Earlier, Bhagirat Rao, who was the director of Himalayan Radio Propagation Unit, prevailed upon me for TIFR to design and construct four 45-foot diameter microwave dishes. There were two in Agra and two in Delhi. So I took all the drawings to Delhi. Already Air Force engineers had discussed in the morning their presentation and how they had done total innovation. The main control station was over ground and they said they had built something underground too so that if the control station got bombed there would be a dummy and be able to keep the link. I asked whether this was field proven. I thought it was a fair question. The meeting went on till 6 pm and I did not budge. Having been in Harvard and Stanford I had gathered a lot of confidence. And also Sarabhai was behind me.

Finally a compromise was made. The drawings could be imported but then ECL would build all the antennas. They built antennas worth hundreds of crores.

IC: Would you like to talk about Mark Price?

GS: What I have said about Mark Price is sufficient.

IC: No, but we didn’t record it.

GS: Mark Price came and then the accident took place in Ooty and we couldn't continue the collaboration. Years later I wanted to collaborate with Joe Taylor (who got Nobel Prize later) but all the young people at Ooty said we could do it ourselves. So I didn't continue the collaboration.

Then in 1970 the question was what independent project I could give to Bagri. Bagri was in electronics but wished to do research work in radio astronomy. Bagri did certain work on two 45-metre dishes and made some initial observations. By 81-'82 the synthesis telescope was there. We knew we could build synthesis telescopes and software was as important as building antennas. It's not only image processing, but data acquisition and controlling antennas far away. Soon after that Bagri ditched us and went away to the US.

In 1976 there was the IAU meeting in France. As we were returning to Grenoble, they announced on the train that it was the last chance to buy things. So I rushed to get a bottle of beer and met this tall well built African scientist with a name tag, Okoye. I said, but the name Okoye seems that of Japanese. He said, 'What do you mean?' I told him about an important paper that had been published a few years ago in Nature by Hewish and Okoye that Crab Nebula had a scintillating source at 38 MHz. In the train, I told him about my idea of possibly constructing a Giant Equatorial Radio Telescope (GERT), similar to the Ooty Radio Telescope but much bigger to be located at a site very close to the Earth's equator. Okoye had worked for his Ph.D degree under the Nobel Laureate, Prof. Tony Hewish. He liked the idea of GERT. He was planning an astronomical school under the aegis of

the International Astronomical Union at his University at Nsukka in Nigeria. He went back to Nigeria after his Ph.D. Okoye invited me to give lectures at the IAU school and thus I went to Nigeria in 1977.

There is a longer history of the GERT project. In 1975, while returning from Peru in South America after attending a conference, the plane to Miami had an unscheduled stop at Belen close to the mouth of River Amazon and I saw flat land close to the earth's equator. I wrote a 10 page note proposing the idea of GERT and sent to a Brazilian scientist whom I had known at Stanford but did not hear back. I had given a copy to Professor Sreekantan who was the Director of TIFR at that time. In early 1977 or so, the Director General of UNESCO was visiting TIFR and suggested that TIFR may support scientific groups in Africa. Sreekantan told me that he made him wait outside the lift on the 4th floor and went back to his room to get the 10-page note I had written about GERT in which apart from Brazil, I had also mentioned Ecuador, Kenya, and Indonesia. The Director General said they would be very interested in such a proposal and soon sanctioned $14,000 for a feasibility study. Using that money, we organized a workshop at Ooty, which was attended by many scientists from various countries in Africa and Asia..

Okoye and I wrote a detailed proposal titled INISSE and GERT (International Institute of Space Sciences and Electronic Sciences) and GERT, with a budget of US$ 20 million with half to be provide d by India and the other half from international sources including the host country. We corresponded with Thom Odiombo from Kenya to be a co-author and he readily accepted and supported the idea. He was the Director of the

International Institute for Insect Physiology; some people think he should have been nominated for the Nobel. Richard Leaky was not part of the proposal.

The famous Swedish inventor, Victor Hasselblad, whose camera was taken to the Moon, donated a lovely bungalow just outside Nairobi to the newly formed Kenya Academy of Science. I met Richard Leaky there who was also founder member of the Academy. Father Leaky and son Richard have appeared on the front page of Time magazine twice or more. They were very famous in the field of archeology.

He asked me about how much money was needed. I said around twenty million dollars. The Government of India was giving around 10 million. He said it was very easy to get 20 million dollars every year. He said we need to meet the president Kenyatta. You know the story of Kenyatta?

IC: Yes.

GS: Tell me his background in one or two sentences.

IC: He is the founder of Kenya.

GS: He is the founder but what is his background? He was found naked by church workers when he was twelve years old. He got educated and went to England. He became part of the Mau-Mau movement and was sentenced to death. An Indian advocate from Bombay saved him. That is Kenyatta for you, who became the president of Kenya.

After Kenya, I wanted to go to Tanzania also. I was very excited because I was born very near the Corbett National Park and I was getting a chance to see Serengeti National Park where the lions are.

So I corresponded with some physicists in Tanzania and everything got fixed. I was paying for my trip to Tanzania. Brother of the mechanical engineer, Mr. Panchal, who designed part of the Ooty Telescope was in Dar-e-Salaam. I told them I would stay till Monday and later visit the well known Serengiti National Park. Thursday morning I got up and there was total silence everywhere. Kenyata had died that morning. I saw a similar mood when Gandhiji died in 1948.

IC: Is that the reason why it didn't work?

GS: Yes the politics began. Leakey and other members of the Kenya Academic of Science strongly supported GERT and but many other scientists in Kenya were not in favour. They wanted to put money elsewhere. Then of course lots of things started happening to Indians in Kenya. But I would still have gone there. It wouldn't have mattered as long as Kenyan scientists were interested.

IC: What about this INISSE?

GS: That is "International Institute of Space Science and Electronics".

IC: Yes I know that. But I wanted to know about the model.

GS: Model was south-south cooperation.

IC: Was it like ICTP?

GS: No ICTP was a totally wrong model. And Bhabha was opposed to it.

IC: So you wanted the practical training centre?

GS: Yes and designing and building things at INISSE locally.

Now in ’81 there was an IAU Regional Committee meeting in Indonesia. And I already had foreign exchange because I didn’t want to go to the Netherlands. In 1979 there was held an important World Conference for Allocation of Frequencies (WARC 79) at Geneva. All frequency bands from ~ 10 Kz to 30 GHz were reviewed and voted by delegations from over 100 countries in the world. Indian delegate on my initiative managed to get approval by the International Telecommunication Union for the protection of the important 322-327 MHz frequency band for radio astronomy against radio frequency interference by ~ 45 votes for and 42 opposed to India’s proposal! We voted out England, France, Netherlands, Germany, Japan, Australia, Philippines, Singapore, Pakistan and many others supporting USA. The Nepalese delegates said, ‘Oh but my ambassador says I should vote for the Americans. But I can take leave on that day.’ So the voting happened and he didn’t come. We became good friends; I used to cook rice for him. I would also go behind the pillar and talk to the Iranian delegates. Americans were unhappy as the band of about 230 MHz to ~ 400 MHz was

being used by them for military purposes. John Findlay as one of the leader of the American delegation was at the ITU. I had applied at the Goddard NASA station and he knew about it.

IC: T.K. Menon was there as well.

GS: T.K. Menon was on a Fellowship at Goddard few years earlier. John Findley told me that I would not get the Fellowship as American delegates are mad in my canvassing African and some Asian delegates to for the protection of the 322-327 MHz frequency band for radio astronomy as this band is part of 220-400 MHz band used by US and European air force for radio communication with ground troops. And I said I didn't care about it. Anyway, Kundu offered me a six-month stay in Maryland. I went there in January '80 for six months.
